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NOTICE OF CHANGE OF ADDRESS.

All communications for the Editor of the "Geological Magazine" should be addressed to R. H. Rastall, Esq., M.A., F.G.S., Christ's College, Cambridge. Letters for Dr. Henry Woodward, F.R.S., to be sent to Tudor Cottage, Clay Hill, Bushey, Herts. Books and parcels, especially from abroad, may be directed to the care of the Publishers, Messrs. Dulau & Co., 34–36 Margaret Street, Cavendish Square, W.1.

EDITORIAL NOTES.

OWING to the release of many geologists and Government workers and the demobilization of old contributors, besides the addition of numerous new ones, we have received, during the past few months, a very large number of important and interesting articles, many of them on subjects of immediate topical interest, and therefore necessitating early publication, and several also needing plates and text-figures for their illustration. Some of our friends have kindly come forward and contributed towards the cost of these necessary but expensive additions to their articles, but owing to the present high prices it is not possible to meet all the requirements of authors in this respect and cover the cost of production with our present circulation. The GEOLOGICAL MAGAZINE is not *primarily* a money-making proposition, nevertheless it is necessary to its continuance that it should at least cover its expenses, and obviously the more copies sold the better value can be given in return. Therefore it behoves our friends, the readers and well-wishers, to use every effort in their power to secure among their associates new subscribers and increase its circulation, which is as essential to the life of a periodical as to that of a living organism.

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A VACANCY having arisen in the body of the Trustees of "The Percy Sladen Memorial Fund" by the retirement, after five years of office, of Sir John Rose Bradford, F.R.S., the Trustees requested the President and Council of the Linnean Society to nominate a successor to the Trust; and they have, in compliance, chosen Dr. Arthur Smith Woodward, F.R.S., President of the Linnean Society, to fill the vacancy for the term of five years.

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The late Dr. S. P. Woodward recorded in his notebook, 1864: "The collection of the late Dr. John Woodward, the founder of the Chair of Geology in Cambridge, originally was kept locked, and a bond for several thousand pounds was given by the Professor for the security of the specimens. Two auditors were appointed yearly by the University to go over the whole collection and compare it with the official catalogue to ascertain the safety of the specimens, and to report to the Vice-Chancellor, who entertained them and the Professor at dinner. The dinner was paid for out of the Woodwardian fund, and the guests were required by the will to drink *burgundy*. The collection consists of about 10,000 specimens, chiefly British fossils. By Woodward's will the Professor must be a *bachelor* and a graduate of the University. The salary was £100, with a further sum for the audit and dinner. The University has lately raised the Professor's salary to £300." It is hardly necessary to add that this salary is now calculated on a more modern and generous basis.

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A highly successful dinner, in honour of those members of the Geological Survey and Museum Staff who have served with His Majesty's Forces, was held at Anderton's Hotel, Fleet Street, on the night of April 30, with Sir Aubrey Strahan in the chair. Forty-eight present and past members attended; of this number twenty have seen active service in one capacity or another. It is to be regretted that distance or other circumstances prevented any of the nine service members of the Edinburgh staff from being fêted also by their colleagues.

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Mr. Harold Cox's pamphlet, *The Coal Industry: Dangers of Nationalisation* (Longmans, Green & Co., 1919, price 6*d*.), should be read by everyone, since there is not a single individual in this country unaffected by the present enormous increase in the price of coal. This rise in price is to a very large extent due to the spread among the miners of ideas based upon unsound premises. Mr. Harold Cox exposes very clearly the fallacies underlying the arguments put forward by the Fabian Society and various miners' organizations deriving their ideas from that source, in favour of nationalization and bureaucratic control, and abolition of royalties. These arguments are shown to be in their way triumphs of irrelevancy and middle-class theorizing founded on out-of-date statistics and applied to problems affecting mainly the relations of capital and labour. It is impossible here to quote these points in detail, but the author's comparison with the Post Office and his remarks on Government departments in general are well worth reading. It is categorically stated in a Fabian pamphlet on nationalization that the State would be able to supply coal at £1 per ton delivered to the cellar. In view of recent developments, largely due to State interference, this makes somewhat ironical reading. With regard to royalties, it is shown that with the present scale of taxation, the State already gets back more than half the total, and

that confiscation of royalties would be not only a breach of faith with those who have acquired a legal right in them, but also an economic blunder, as in countries where minerals are in theory national property the State does not appear to get as much as it does in Great Britain; and after all the total amount of royalties is but small in comparison with the actual value of the mineral output of this country.

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At a Special General Meeting, held on June 25 last, the Geological Society of London decided to raise the annual contribution of Fellows elected after November 1, 1919, to three guineas per annum. This step was rendered inevitable by the enormous increase in expenses of all kinds, and especially by the greatly enhanced cost of publication of the Quarterly Journal and other literature issued by the Society. This is undoubtedly one of the most important functions of the Society, and some sacrifice is necessary on the part of geologists if its usefulness in this respect is not to be impaired. The cost of publication must in any case necessarily be very heavy in the immediate future, as a good deal of leeway still has to be made up in the Quarterly Journal and the index of current literature, and it remains to be seen whether the step already taken is sufficiently drastic. At the same meeting it was decided to adhere to the present hour for meetings, 5.30 p.m. This decision will rejoice the hearts of all those Fellows who live within a couple of hours or so of London. At the present time, it is no small undertaking to spend a night in town, owing to shortage of hotel accommodation. Residents within 70 or 80 miles of London can usually return home after an afternoon meeting, whereas an evening meeting makes this impossible. Those coming from further afield must in any case stay in town, hence the present arrangement possesses many advantages and does no harm to any one. It has the additional good feature of making a shorter day for the permanent officials, whose hours on meeting-days, under the old arrangement, were unreasonably long.

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A fine collection of minerals of economic value was lately exhibited in London, on behalf of the Government of one of the Dominions. Even more interesting than the specimens themselves was the knowledge of mineralogy displayed by the officials responsible for the preparation of the explanatory labels. The following are some specially illuminating examples culled from this source:—*Apatite Sugar:* Mineral sugar is a poisonous salt. *Manganite:* A mineral occurring in crystals. *Molybdenite:* A soft mineral containing a great deal of sulphur, often known as "amber mica". *Galena:* A lead ore, formed by the action of sulphur on a non-metallic element. *Pyrrholite:* Name means "fire-light stone", another variety of serpentine. *Ilmenite:* Taken from Ilmen Hills. Composed of tartaric acids and oxides of iron. *Sphalerite:* Name comes from word meaning treacherous. Better known as "blende", which comes from a word meaning to dazzle—a sulphide of arsenic.

ORIGINAL ARTICLES.

I.—Non-German Sources of Potash.

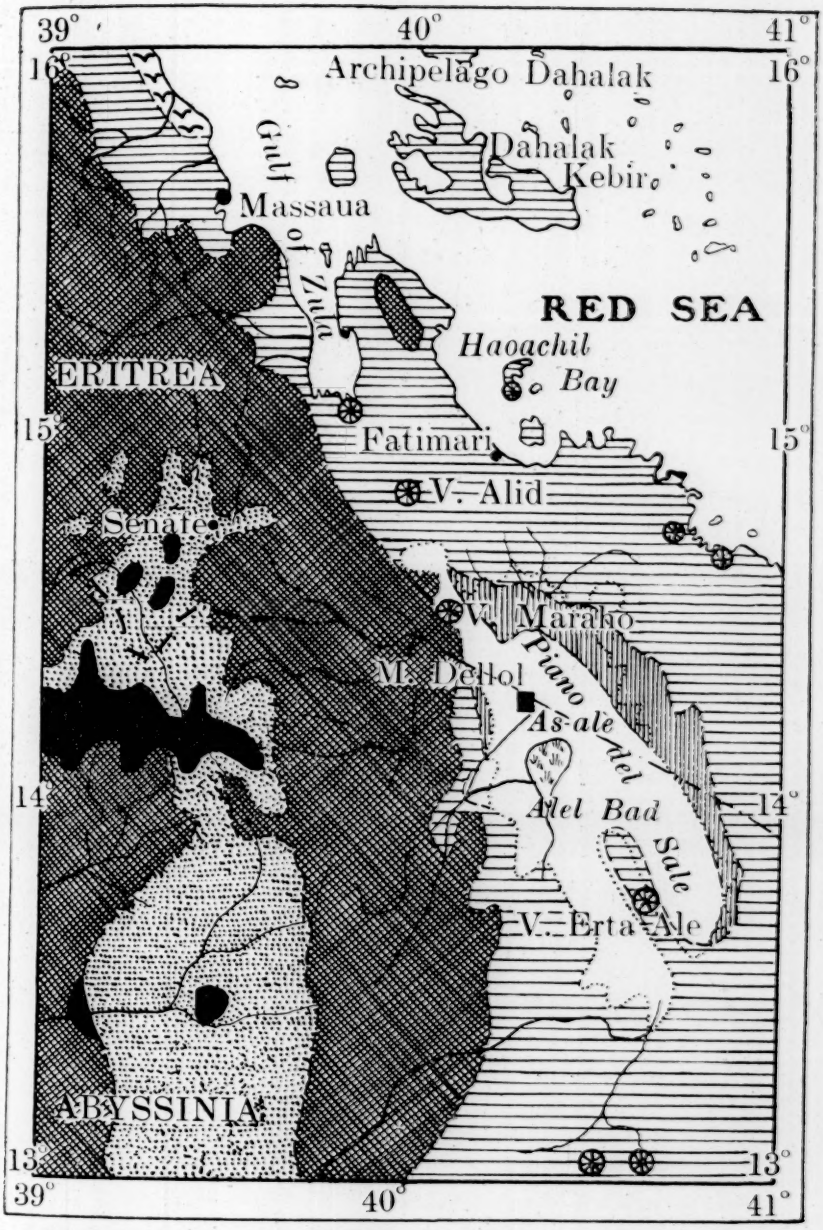
By Arthur Holmes, D.Sc., A.R.C.S., F.G.S.

Abyssinian Deposits.—During 1911 an Italian resident in Eritrea discovered a remarkable occurrence of potash salts in the *Piano del Sale*, near the provisional boundary between the Italian colony and Abyssinia. On account of its equivocal situation, development was somewhat handicapped during the early stages by Abyssinian hostility. Fortunately these preliminary difficulties were successfully overcome, and the deposit proved to be of great assistance to the Allied Powers during the war. The rate of production has gradually increased, and the estimated output for 1918 is stated to be equivalent to 50,000 tons of KCl.

The situation of the deposit is indicated on the accompanying geological sketch-map by a black rectangle (due south of the Bay of Haoachil, and just touching the recently determined boundary) which marks the position of Mt. Dellol. The *Piano del Sale*, or "Plain of Salt", is a depressed region almost entirely below sea-level. It is, in fact, as indicated on the map by a dotted line,[1] approximately bounded by the contour of sea-level. The depression is separated from the Red Sea, of which it is structurally a part, by the lavas and sediments of the Aden Series. On the west the edge of the Abyssinian plateau, carved in an ancient complex of metamorphic and igneous rocks, constitutes the real western boundary of the Red Sea Rift, and forms one side of the funnel-shaped sunkland into which the East African Rift Valley opens out near Ankober. The *Piano del Sale* is itself the exposed basin-like surface of a gigantic saline deposit, in which the older beds are disposed around the periphery, while the younger beds outcrop at successively lower levels towards the interior. Beds consisting mainly of gypsum, and representing the earliest phase of deposition, outcrop conspicuously around the northern and eastern sides, and similar beds also appear on the western edge, opposite Mt. Dellol. Within the gypsum zone, and at a lower level, though resting upon it, is a wide expanse of rock-salt over 20 miles across, and generally free from alluvium. The level gradually drops until it reaches about 390 feet below sea-level around Mt. Dellol. This so-called "mount" is a rectangular mass consisting mainly of rock-salt, the summit of which is within a foot or two of sea-level. It has been weathered into curious castellated forms, so that when seen from a distance in the slanting rays of the sun it resembles a vast mediæval fortress.

At the south-eastern corner of this curious edifice, in the heart of the depression, red and yellow masses of sylvite are exposed at the

[1] For a map showing the relation of this area to the Red Sea and to the Rift Valley of East Africa, see G. Dainelli & O. Marinelli in *Atlante d'Africa*, by A. Ghisleri, 1909, p. 139, fig. 6. The information from which the geological sketch-map was compiled was mainly obtained from this publication (see pls. xxxi, xxxii, and pp. 133–9).



GEOLOGICAL SKETCH-MAP OF PARTS OF ERITREA AND ABYSSINIA.
Scale, 1 inch = 34 miles.

surface. Over an area of 200,000 square yards sylvite has been proved to a depth varying from 2 to 5 feet. The average content of KCl in this part of the deposit amounts to 80 per cent, while locally the purer material exceeds 98 per cent of KCl. Small quantities of NaCl are present, and also traces of $MgCl_2$, bromine, and iron oxides. Surrounding the sylvite and extending over an area ten times as great, carnallite is found to a depth of 150 feet. This is the greatest depth reached by the boreholes, and even near the junction of the carnallite with the surrounding rock-salt the lower surface of the former had not, in 1918, been reached, suggesting a plug- or funnel-like mode of occurrence. The carnallite beds average from 25 to 15 per cent of KCl according to the depth, but it is possible, without difficulty or special plant, to prepare for export much richer material. The carnallite is exposed to the sun as it is dug, and at the relatively high temperature normal to the district it becomes unstable, and liquefies in its own water of crystallization. From the solution so produced most of the KCl is directly deposited, leaving a mother-liquor which is concentrated with respect to carnallite, but which is still unsaturated with respect to $MgCl_2$. By allowing this liquor to flow away, a high proportion of the $MgCl_2$ is removed. The first effect of the evaporation of the liquor is the redeposition of carnallite, and although it is stable in the presence of $MgCl_2$ solution, it breaks down as before when the $MgCl_2$ flows away. The process is allowed to continue on these lines until finally a residue containing over 80 per cent of KCl remains to be packed for transport to the coast.

The saline deposit as a whole displays an unusually complete sequence, and is clearly the result of evaporation in an arm of the Red Sea cut off permanently or intermittently by the volcanic hills of the present coast. Associated phenomena, however, indicate that volcanic agencies have also contributed to the development of the deposit. A series of springs rises through the carnallite zone, varying in temperature from 50° C. to 90° C. These consist essentially of saturated solutions of $MgCl_2$, with appreciable quantities of bromine and small amounts of sodium, potassium, and iron.[1] At the north-eastern corner of Dellol a deposit of "brimstone" has been found, surrounded by a deep bed of "flowers of sulphur". The latter mode of occurrence points indubitably to condensation of the sulphur, either directly from the gaseous state or from the interaction of gaseous sulphur compounds. The hot springs, the sulphur deposit, and the abundance of volcanic activity in the neighbourhood add extraordinary interest to the area, and it is to be hoped that an authoritative description and interpretation may soon be forthcoming.

The southern part of the *Piano del Sale* has not yet been thoroughly explored, and as it contains various focal points of depression there is a reasonable possibility that other areas of potash salts still await discovery. Political considerations are likely, however, to prevent development in this direction, at least for the present, since the

[1] The springs are described in an Italian paper by M. Giua, of which an English summary is published in the Journ. Soc. Chem. Ind., vol. xxxvii, p. R 460, 1918.

Abyssinians are very jealous of the economic invasion of their territory.

The Dellol deposit itself is now definitely known to be within Abyssinia, though it is worked by an Italian Syndicate under concession from the Abyssinian Government. Conditions of labour are far from pleasant, as the region is one of extreme aridity, while the average temperature in the shade is over 120° F. Nevertheless, in spite of climatic difficulties, there were at one time nearly 8,000 men employed in mining the potash, making a road to the coast, and building a port at Fatimari, a tiny settlement on the Bay of Haoachil, 46 miles to the north of Dellol.[1] Early in 1917 arrangements were made for constructing a light railway to Fatimari, and by now this should have taken the place of camel transport, for at the end of last year the track was rapidly approaching completion.

For many of the details made use of in the above description I am indebted to Captain Cockerell, the Controller of the Department of Mineral Resources Development of the Ministry of Munitions, and to Mr. Henry C. D. Blattner, who spent some months in examining the deposit during the early stages of its commercial development.

Natural Brines.

Since potassium salts are among the most soluble of the saline materials contained in natural waters, they become gradually concentrated as evaporation proceeds, and are finally deposited from the brines that lie over the crystalline body already deposited, or from the mother-liquors that occupy its pores. In various arid regions there are more or less desiccated lakes from which potash-rich brines are extracted; notably in the United States and Tunis. Here also the salt-marsh of Salin-de-Giraud in the delta of the Rhône may be mentioned, though the output of KCl derived from the evaporation of its waters is comparatively small.

Searle's Lake.—The deposit to which this name is applied occurs in a depressed and elongated basin-like region in the north-eastern corner of San Bernadina County, California.[2] During the Glacial epoch the basin, which is nearly surrounded by abruptly rising hills, was occupied by a lake whose surface stood 640 feet above the level of the present floor. A firm but very porous sheet of white salts now lies exposed over an area of 12 square miles, and laterally the deposit extends still further beneath the surrounding mud-flats. Down to a considerable depth rock-salt is the chief mineral found, but below 12 to 20 feet from the surface irregular layers are found rich in trona or thenardite, and rarely in sylvinite. The deposits have provided a rich suite of minerals, the genetic study of which, as yet scarcely begun, will rival in interest that of the Stassfurt salts.

Except quite near the surface, the interstices of the crystal aggregates—amounting to 40 per cent by volume—are occupied by a highly concentrated brine, and from this the American Trona Corporation extracts a number of salts, including KCl. The brine, which has the composition set forth in the table below, is known to

[1] *African World*, August 18, 1917.

[2] A. de Ropp, Journ. Ind. & Eng. Chem., vol. x, p. 839, 1918.

amount to over 110,000 million gallons, averaging about 4 per cent of KCl, and, therefore, containing 24 million tons of that salt.

COMPOSITION OF AMERICAN POTASH BRINES.

Saline Constituents.	*Searle's Lake, California.*	*Jesse Lake, Nebraska.*	*Salduro Salt Marsh, Utah.*	*Great Salt Lake, Utah.*
KCl	13·5	10·0	7·03	3·16
K_2SO_4	—	31·5	—	—
K_2CO_3	—	13·0	—	—
NaCl	46·3	—	81·04	75·91
Na_2SO_4	19·2	—	1·98	9·52
Na_2CO_3	13·0	45·5	—	—
$Na_2B_4O_7 . 10H_2O$	8·0	—	—	—
$CaSO_4$	—	—	0·88	0·34
$CaCO_3$	—	—	—	0·15
$MgCl_2$	—	—	9·07	10·92
	100·0	100·0	100·0	100·0
Percentage of salts in solution	35·8	19·3	27·1	20·0

During the evaporation processes, sodium carbonate and sulphate, and borax are produced, and finally crude potassium chloride (75 to 80 per cent KCl) is recovered. At the present rate of working, from 50,000 to 60,000 tons of the crude salt are produced annually, together with one quarter that amount of borax.

Other American Brines.—In Nebraska an area of some 8,000 square miles is occupied by sand-dunes, interspersed with flat-bottomed lakes or salt marshes. These represent every stage of evaporation, from nearly fresh water to residual brines. The "lakes" are generally underlain by green muds and beds of sand, the latter containing the whole of the brine when superficial water no longer remains. The potash-content varies from 9 to 35 per cent of the dry salts, and when commercial operations on the richer brines were undertaken in 1915, they met with such success that the following year's results gave Nebraska first place in the United States as a producer of potash.[1] Jesse Lake[2] is the most important of the basins from which brine is pumped, and a statement of its composition is listed above. The sands of the dune area are rich in orthoclase and microcline, but in a semi-arid climate it is unlikely that much potash can have been derived directly from such a source. The richness of the brine in carbonates suggests that its dissolved contents represent an accumulation of wind-blown ashes from years of prairie fires, concentrated by intermittent surface drainage.

In Utah potash was recovered from the brine of Great Salt Lake during 1916 and in later years, but, as the analysis shows, it is unlikely that the production can continue to compete with that from more favoured sources. In the Salduro Salt Marsh,[3] however, Utah

[1] Eng. & Min. Journ., vol. civ, p. 827, 1917.
[2] E. E. Thun, Met. & Chem. Eng., vol. xvii, p. 693, 1917.
[3] Eng. & Min. Journ., loc. cit.

possesses a more valuable deposit which somewhat resembles Searle's Lake; but here the salt crust is only 3 to 5 feet in thickness, and the brine is not only less concentrated than in Searle's Lake but contains less potash relatively to the other constituents.

Tunis.—South of Gabes (long. 10° E.), in the lowland of the Tunisian Shotts, a salt lake is worked for both bromine and potash. A product known as "sebkainite", which contains about 34 per cent of potassium, is obtained by solar evaporation of the brine. Commercial exploitation began in 1915, and the present rate of extraction is equivalent to over 1,000 tons of KCl per month. The plant now being installed will gradually increase the production to four times the present output, and will make possible the export of the pure chloride, refined on the spot from crude salt such as is now obtained.

Saltpetre.

Deposits of potassium nitrate are generally of organic origin, but in Chile a small proportion is associated with the sodium nitrate deposits, and in Brazil a deposit has recently been discovered containing 89 per cent of KNO_3. In the Eocene marls and limestones of Fergana in Central Siberia saltpetre has been found to the extent of between 2 and 5 per cent over a very considerable area, and as fuel (coal and petroleum) is abundant in the same district the conditions appear to be favourable for its extraction. India, however, is the only large-scale exporter of saltpetre, Behar being the chief district from which it is obtained. The conditions of its formation are well described in the *Review of the Mineral Production of India, 1909–13*, from which the following paragraphs are extracted[1]:—

"For the formation of saltpetre in a soil the necessary conditions are:
(1) Supplies of nitrogenous organic matter;
(2) climatic conditions favourable to the growth and action of Winogradski's so-called nitroso and nitro bacteria, converting urea and ammonia successively into nitrous and nitric acids;
(3) the presence of potash: and
(4) meteorological conditions suitable for the efflorescence of the potassium nitrate at the surface.

An ideal combination of these necessary circumstances has made the Behar section of the Gangetic plain famous for its production of saltpetre.

"In this part of India we have a population of over 500 per square mile, mainly agricultural in occupation, and thus accompanied by a high proportion of domestic animals, supplying an abundance of organic nitrogen. . . .

"With a population largely using wood and cow-dung for fuel, the soil around villages naturally would be well stocked with potash, and, finally, with a period of continuous surface desiccation, following a small rainfall, the subsoil water, brought to the surface by capillary action in the soil, leaves an efflorescence of salts, in which, not surprisingly, potassium nitrate is conspicuous. Under these conditions Behar has for many years yielded some 20,000 tons of saltpetre a year."

Kelp.

Since the beginning of the eighteenth century seaweed has been utilized along various parts of the Scottish and Irish coasts as a source of potash and iodine, but owing to foreign competition the

[1] Sir T. H. Holland & L. L. Fermor, Rec. Geol. Surv. India, vol. xlvi, pp. 210–15, 1915.

industry had long before the war fallen to very small dimensions, and even since 1914 it has not been appreciably revived. The home contribution of potash during the war from kelp[1] was, indeed, barely sufficient to supply the $KClO_3$ required for the manufacture of matches.

Along the Pacific coast the kelp industry has developed on an enormous scale under the impetus of the demand for acetone and potash that arose early in the war. Giant seaweeds are harvested directly from the sea by floating mechanical reapers. After the weed is dried and burnt, the resulting ash contains salts equivalent to about 15 per cent of K_2O. As a method leading to potash recovery alone—that is, without the collateral separation of by-products—this process was found to be wasteful, and even when the ash was sold directly as a fertilizer it was not found possible to compete with other sources of supply. Consequently more economical methods of treatment have been devised, the most successful being that in which acetone is prepared as the main product, with potash as a by-product. At San Diego the seaweed is fermented in large bins, and the resulting solutions (containing crude acetic acid with KCl and iodine compounds) are collected. Calcium acetate is formed by neutralizing the acid with limestone, and by its ignition acetone is formed. Meanwhile potassium chloride and iodine are concentrated in the residual liquors, and are ultimately separated in a crude state. The three products taken together have provided satisfactory profits under war conditions, but the future stability of the industry is less certain, especially as, in common with Searle's Lake, the site of production is far removed from the principal centres of demand.[2]

Other Organic Sources.—The fact that 90 per cent of the potash used in Great Britain is devoted to fertilizing purposes, is clearly an indication that the plants which absorb potash from the soil may themselves be utilized for its subsequent replenishment. Among important crops, flax and potatoes in particular require large quantities of potash for continued growth. It is, however, not possible to produce potash economically from waste vegetation except as a by-product in already established industries. Even in the lumber camps of Canada the wood-ash from saw-mills waste contains insufficient potash to justify its collection and treatment, and its only value is as a local fertilizer applied to the land directly.[3] In Belgium and Italy potassium salts (K_2CO_3, KCl, and K_2SO_4) are recovered from the residual liquors left after the treatment of molasses in beet-sugar factories. In the Caucasus district there was formerly a considerable local potash industry dependent on the

[1] The ash or slaggy matter that remains when seaweed is burnt in a kiln for six or eight hours is called *kelp*; but in the United States the weed is *kelp*, and the product *kelp-ash*. The ash, as obtained on the west coast of Scotland, contains about 18 per cent of KCl and 13 per cent of K_2SO_4.

[2] Since writing this paragraph I have been informed (April 24, 1919) by the Controller of Potash Production that most of the American kelp recovery plants have been shut down since the effective termination of the war. See also Journ. Soc. Chem. Ind. (June 15, 1919) for a recent statement of the potash position in the United States.

[3] *The World's Supply of Potash*, Imperial Institute, 1915, p. 25.

collection of sun-flower stalks from the Russian peasants, and no doubt under settled conditions this source will again become productive. Cream-of-tartar is a by-product of the wine industry, and is exported in large quantities from France, Italy, and other wine-producing countries.

Reference to the chief animal source of potash has already been made in connexion with saltpetre; wool, grease, and dried sweat (suint) remain for brief consideration, for this material, the waste product from processes of wool-scouring, contains the potash salts of various fatty acids. In France and Belgium K_2CO_3 has been recovered from suint liquors for several years, and under war conditions its extraction was commenced in Britain. Incidentally the treatment of suint is to be advocated, if only to avoid the fouling of rivers which attends the usual method of its disposal.

Insoluble Potash Minerals.

The chief silicate minerals rich in potash are felspars (orthoclase and microcline), leucite, micas, and glauconite, while a mineral which may conveniently be considered with these is alunite, a basic sulphate of potassium and aluminium.

Felspars.—Although numerous attempts have been made to devise a commercially successful method of separating potash from felspar, none has yet satisfactorily emerged from the experimental stage, except possibly where the separation is introduced into, and made part of, the process of manufacturing Portland cement (see below, p. 348). In Britain[1] our potash-felspars are not well situated, and the cost of quarrying and carriage forbids their utilization as a source of potash, and is likely to do so unless the very bulky residue can itself be employed in a profitable capacity.

Leucite.—Leucite contains about 19·5 per cent of potash, and as it is readily decomposed by acids, giving a solution of potassium and aluminium salts, it certainly provides a more favourable material for treatment than felspar. The leucitic lavas of the Italian volcanoes contain between 8 per cent (leucite-tephrite) and 10 per cent of K_2O (leucite-phonolite), and those of the Leucite Hills in Wyoming[2] average 10 per cent; consequently these rocks might be treated directly, and they are undoubtedly a valuable potential asset to the countries in which they occur. H. S. Washington[3] has recently drawn attention to this comparatively neglected source of potash in an elaborate review of the Italian lavas, in the course of which he estimates the reserves of potash in the seven leucitic volcanoes, extending from Vesuvius to Bolsena, at a minimum of 10,000 million tons. The corresponding American resources are but a fiftieth of this amount, and are, moreover, less favourably situated with respect to industrial centres. Already, in both areas, the rocks have been used directly as fertilizers, and the American Potash Company has

[1] Mem. Geol. Surv., Spec. Reps. on Mineral Resources, vol. v (Potash-Felspar, etc.), 1916; P. G. H. Boswell, Trans. Soc. Glass Technology, vol. ii, p. 35, 1918.

[2] R. C. Wells, U.S.G.S., Prof. Pap. 98 D, p. 37, 1916.

[3] Met. & Chem. Eng., vol. xviii, p. 65, 1918.

been formed to extract potash from the Leucite Hills,[1] but little progress has as yet been reported, while in Italy the problem is still a subject of active research.

Glauconite. — British "greensands" rarely contain more than 4 per cent of potash, and consequently they fail to provide a practicable source. In the United States, however, potash has already been successfully recovered from glauconitic sands and marls. A narrow belt of Upper Cretaceous greensand extends from Sandy Hook to Virginia, and in many parts of New Jersey glauconite is so abundant that the air-dried sediment contains from 6 to 7 per cent of K_2O, three-quarters of which can be liberated by the process adopted. Glauconite has the advantage over felspar of being practically free from alumina and soda. To remove the latter impurity from potash concentrates is somewhat troublesome, and the alumina, if extracted by digestion, requires so high a proportion of water that the expense becomes prohibitive. In the case of glauconite a similar method of treatment can be applied at a comparatively low cost. The process involves digesting with high-pressure steam a mixture of the finely-ground raw material with lime. The resulting filtrate contains potash with little impurity (80 per cent KOH on evaporation), while the residue contains cementitious constituents, and is utilized in the manufacture of bricks and tiles.

Alunite.—This mineral, the composition of which may be represented by the formula $K[Al(OH)_2]_3(SO_4)_2$, is readily decomposed by calcination; sulphuric acid is driven off, together with all the water, leaving a residue of soluble K_2SO_4 and insoluble alumina. Although alunite has been generally used as a source of alum, in recent years high-grade potassium sulphate has been prepared from it, the first successfully operated plant having been established in Utah. Alunite occurs in veins, and disseminated through the adjacent rocks, in certain volcanic regions, where it is produced in association with propylitization, by the action of hydrothermal emanations containing sulphuric acid or its constituents. The chief localities where it is actively mined are Marysvale, Utah; Goldfield, Nevada; Bullah Delah, New South Wales; La Tolfa, Italy; and Almeira, Spain.

Recovery of Potash from the Dust of Cement Kilns.

Several years ago the fruit-growers in the vicinity of the Riverside Portland Cement Company, California, complained that the dust from the kilns caused serious damage to their crops. In consequence the Company took steps to abate the nuisance, and installed an electrical precipitation plant to settle the dust. Hoping that the dust might be of some economic value, and so might contribute towards the cost of its collection, analyses were made, and it was found that it contained 10 per cent of potash. Expectation was thus amply fulfilled and the recovery of potash was at once developed as a profitable by-product.[2]

[1] A. H. Rogers, Met. & Chem. Eng., vol. xv, p. 387, 1915.
[2] L. Bradley, Journ. Ind. & Eng. Chem., vol. x, p. 804, 1918.

During the last two years experimental plants have been run by certain British firms for the same purpose, and although the raw materials generally contain only a very small proportion of potash, the quantities of cement manufactured are so great that a considerable output of potash is potentially available from this source. Unfortunately, no authoritative statement has yet been issued of the results of the processes so far tested. As a further development, the scope of the experiments has recently been extended to test the suggestion that potash-felspar might advantageously be substituted in part for the clay used as a raw material. When one part of orthoclase is intimately mixed with three parts of calcium carbonate, and the mixture heated to 1,300°–1,400° C. for about an hour, potash is volatilized, and the residual clinker corresponds in composition with that of Portland cement as normally prepared. Similarly, when the mixture is digested with steam at a pressure of from ten to fifteen atmospheres, a solution is obtained containing as hydroxide 90 per cent of the potash originally present in the charge, and the residue is again a Portland cement clinker.[1]

There can be little doubt that the cement industry could, if necessary, supply very substantial quantities of potash by developing along these lines; but on the other hand the incentive of urgent national need having now passed, and the attraction of high prices being but temporary, it is unlikely that the extraction of potash from felspar by this means will become a peace industry.

Blast Furnace Flue-dust.

Among the various methods exploited in Britain with a view to developing our home resources, the recovery of volatilized potash from blast-furnace flue-dust and gases has emerged as the most fruitful. Potash is present in small quantities in all the materials charged into the furnaces, iron-ore being regarded as the principal source. Iron-ores vary greatly in their potash content, the figures ranging from 0·2 to 2·5 per cent. The ash from coal contains from 0·2 to 0·7 per cent, but it is possible that these figures do not adequately express the potash content of the original coal, as they do not include potash that may have been volatilized during combustion. That coal may possibly supply more potash than is usually recognized, is indicated by the fact that in certain experimental runs the potash balance-sheet actually revealed a greater recovery of potash than the amount estimated to be present in the raw materials fed into the furnace. Generally, however, the balance-sheet shows a more or less marked deficit.[2]

Since the early part of 1915 a series of valuable experiments have been carried out by Mr. Kenneth M. Chance[3] of the British Cyanides Co., Ltd., and Mr. Lennox Leigh, of the North Lincolnshire Iron Co., Ltd. It was found that the volatilization of potassium as chloride could be greatly increased by adding to the charge a small

[1] W. H. Ross, Journ. Ind. & Eng. Chem., vol. ix, p. 469, 1917.

[2] R. A. Berry & D. N. McArthur, Journ. Soc. Chem. Ind., vol. xxxvii, p. T 1, 1918.

[3] Journ. Soc. Chem. Ind., vol. xxxvii, p. T 222, 1918.

percentage of common salt. The conditions for successful working on a large scale have been carefully investigated, with a view to controlling the introduction of salt so that the products of volatilization should not be deleterious to the quality of the iron or to the furnace linings. The success of the experiments led to the formation of the British Potash Co., Ltd., for the commercial recovery of potash from flue-dust supplied by the blast-furnaces of Lincolnshire. It is estimated that the blast-furnaces of the country should be able without difficulty to contribute at least 50,000 tons of potassium chloride per annum, an amount approximately one-half of our pre-war imports of potassium salts. Thus the fear that Britain will ever again experience a shortage of potash as acute as was suffered in 1916–17 is completely dispelled. At the same time it appears to be certain that the country can never be completely self-supporting, unless, perhaps, the dormant exploration[1] of British saline deposits for potash is continued with success.

II.—The Igneous Rocks of the Ashprington Area.

By Miss I. H. Lowe, B.Sc., Demonstrator in Geology, Bedford College, University of London.

1. Introduction.

In South Devon the outcrops of Middle Devonian igneous rocks form a series of roughly parallel bands, which broaden out and occupy a continuous area about twelve square miles in extent in the neighbourhood of Ashprington village. No detailed account of the petrological characters of these rocks has been given, although similar types have been described fully in the Plymouth Survey Memoir. For this reason, and also in the hope that further study might explain more completely the cause of the broadened outcrop, I investigated many exposures in the Ashprington area.

A large number of specimens were collected from this district, a general survey of which showed that the determination of the relations of the rocks to each other over any but limited areas was difficult. This was due to the isolated character of the outcrops, the comparatively rapid change in the rocks exposed, the difficulty of tracing bedding planes owing to the development of a marked cleavage, and the absence of sections showing junctions. In consequence a more detailed study was made of a small area east of Harbertonford village, covering about two square miles (Fig. 1). This was chosen because there were numerous exposures in a limited space, and the structure is typical of that throughout the district.

The rocks examined are all basic in composition and strikingly uniform in character, and are either diabases or fragmental basic rocks. Many of the specimens collected cannot be definitely classified owing to the amount of alteration they have undergone. The absence of acid igneous rocks is very noticeable; a rotten felsitic rock from a recess in the road from Gerston Cross to Totnes was the only specimen obtained.

[1] Journ. Soc. Chem. Ind., vol. xxxvii, p. R 313, 1918.

The field work necessitated a series of visits on which Dr. Raisin accompanied me, and I should like to express my gratitude to her for the unfailing help she has given me in this work, and to Dr. H. H. Thomas, who kindly made some valuable suggestions. The work was carried on in the Geological Department of Bedford College.

2. The Field Relations of the Igneous Rocks.

A general account of the field relations of the volcanic rocks to the sedimentary in the Ashprington area is given by W. A. E. Ussher in the Geological Survey Memoir of Torquay (pp. 77 et seq.).

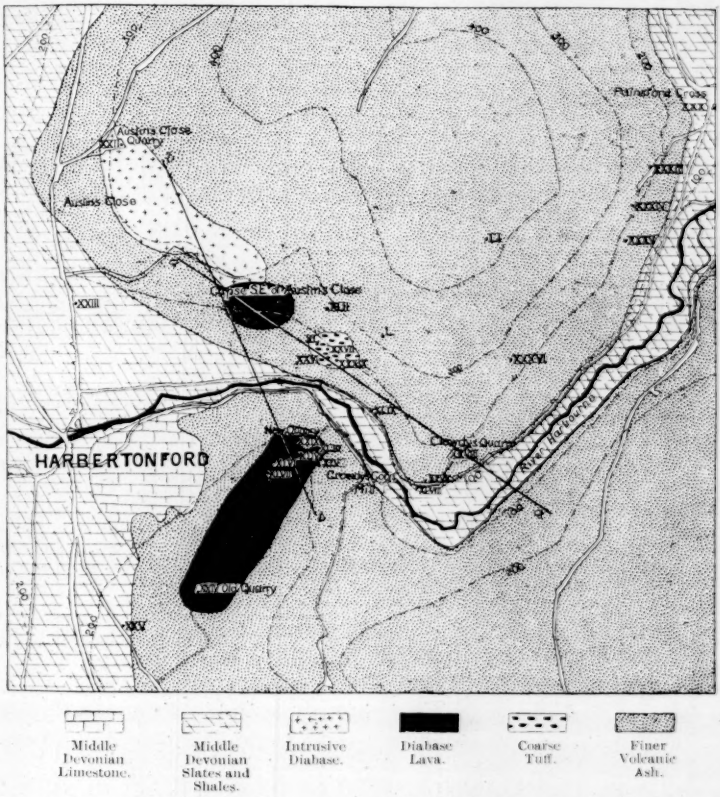


Fig. 1.—Map showing the outcrops in the Harbertonford area. Scale, 4 inches = 1 mile (approx.).

The exposures[1] of igneous rock in the area east of Harbertonford are shown in five quarries, and form crags on the slopes of the hills

[1] The exposures to which reference is made are marked on the accompanying map by Roman numerals.

facing the Harbourne River. The contour of the ground did not seem to be dependent on the nature of the rocks, and could not be relied upon in tracing the extent of any one type.

North of the River Harbourne diabase alone is exposed in Austin's Close quarry (XXII) and in several crags in a copse to the south-east (XLI). Eastward of this, in Crowdy's quarry (XXVIII), there is a more varied section, at the base of which fine greenish-grey banded ash is shown, followed by a layer of calcareous ash containing fragments of crinoid stems and casts of brachiopods and corals, and passing up into an impure fossiliferous limestone. Above this is an amygdaloidal lava, succeeded by ashy and concretionary calcareous bands. The beds in this quarry are gently undulating, the axes of the folds running east and west. Similar sections in which ashy and calcareous bands alternate are exposed on the banks of the River Dart; from these, recognizable fossils have been obtained and are described in the Torquay Survey Memoir (p. 81). To the south of the River Harbourne, in a recently opened quarry, which will be referred to as "New quarry" (XXIX), the rock is worked from a platform about 50 feet above the level of the entrance. The section exposes at the base much cleaved fine ashy material, forming the walls of the approach to a slide down which the quarried material is shot. Above this a coarser green ash with whitish patches and silvery cleavage surfaces forms the platform, and is succeeded by a dark-green amygdaloidal diabase, which also crops out as crags on the hill above. The dip of these rocks is practically horizontal. To the south, in the same hill, is a quarry (XXIV) largely overgrown, where the rock exposed is diabase, red in colour from long-continued weathering.

To the south-east of Austin's Close, forming crags in a hedge (XL, XXVII, XXVI), a rock occurs containing large fragments (9 by 4 inches and 10 by 3 inches). The fragments are splintery, subangular, and greyish-white in colour, embedded in a tough green rock. The matrix showed irregular hollows on the weathered surfaces; these hollows have a distinct linear arrangement, and may represent cavities from which other fragments have been worn. The cleavage planes cross these lines and dip to the south-east at 45°; a dip which is very constant throughout the area (Fig. 2). Rocks collected from higher up on the hill (XLII, L, LI) and on the south-east slope of the hill (XXXIII–XXXVI) were not easy to distinguish as either diabase or ash.

3. Petrological Characters of the Igneous Rocks.

(1) *Diabases.*

Throughout the Ashprington district diabase, when freshly exposed, is dark green, tough, compact, and frequently amygdaloidal. The amygdales often have a linear arrangement, are not more than an inch in length, and are filled with a fine aggregate of chlorite, sometimes associated with epidote. A few of the diabases are slate-grey in colour; the one from Down's Hill quarry, a quarter of a mile south of Totnes, is an example of this type. It contains exceptionally large banded amygdales several inches in diameter,

filled with quartz, chalcedony, calcite, and hæmatite. The red and brown colour of the rocks in the area is especially characteristic of those exposed in road cuttings and old disused quarries. The specific gravity of the fresher specimens varies from 2·87 to 2·98.

The rocks are cleaved and generally show curved irregular joint planes; but typical "pillow structure", such as that developed in the spilite in Chipley quarry and described in the Newton Abbot Memoir (p. 54), is only shown in one exposure in a small road cutting just outside Cornworthy village. A large pillow is exposed, showing numerous small vesicles arranged in concentric bands; the material of which it is formed is dark brown, but is too rotten to allow of microscopic examination.

Narrow veins are abundant in all rocks, frequently intersecting and crumpled or faulted. The minerals filling the veins are quartz, epidote, chlorite, actinolite, asbestos, and calcite.

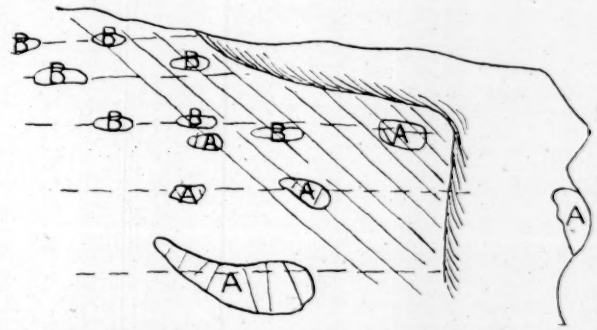


FIG. 2.—Diagram illustrating the arrangements of the coarse fragments in the crag at exposure XXVII. *A* = imbedded fragments, *B* = the cavities resulting from the weathering out of the fragments. Continuous lines represent the direction of the cleavage planes. Broken lines represent the bands along which the fragments are arranged.

One of the least decomposed of the diabases is that exposed in a quarry at Stancombe Linhay, two miles south of Totnes. When examined under the microscope the rock was seen to be sub-ophitic and to contain fairly large, fresh, pale puce-coloured crystals of augite, which are irregular in shape, slightly pleochroic, and are abundantly penetrated by very small lath-shaped felspars. In most of the diabases the augite is only recognizable under a ¼ in. objective. They are all noticeably rich in felspar, which must have been originally the most abundant constituent of the rock. Most rocks show two generations of felspar; those of the earlier are well-formed phenocrysts, the sections of which are elongated and rectangular or rhombic in shape. Some of the felspars show evidence of corrosion, having rounded angles, and in the rock from Down's Hill quarry containing devitrified glass inclusions. The crystals vary in size, from microscopic to large macroscopic, one in a specimen from Austin's Close quarry measuring 85 sq. mm. The felspars of the second generation are small and lath-shaped; in the ophitic diabases they penetrate the augite, and in the non-ophitic types

usually have a parallel arrangement due to flow. All the felspars are much decomposed, a few still show signs of repeated twinning, the angles of symmetrical extinction of these indicate oligoclase or albite-oligoclase. The refractive index, when compared with that of the Canada balsam, is, as far as can be determined, in agreement with this identification. Skeleton crystals of ilmenite occur in the rock from Stancombe Linhay, and are also irregularly developed in other diabases. Apatite is rare, and is only present in the diabase from Down's Hill quarry; even in this rock it is slight in amount.

All the rocks are very much decomposed; the resulting products include chlorite, epidote, granular sphene, actinolite, white mica, and a mosaic of a clear colourless mineral, probably quartz. The chlorite occurs very abundantly in decomposed felspars, both in veins traversing the crystals and in the felspar itself; it also forms elongated irregular patches in all the rocks. Epidote is abundant in flocculent aggregates of fine granules both in the felspars and throughout the slides, and also as distinct crystals. Actinolite is present in some specimens in the form of scattered needles, in others forming a fringe from the edge of augite crystals. In one specimen the development can be seen to have taken place to such an extent that practically the whole section consists of patches of actinolite, the needles in each patch being parallel and extinguishing simultaneously. Brown hornblende is very rare, but a few small, ill-defined flakes occur in a slice of the rock collected from the old quarry south of Harbertonford. Granular sphene is associated with leucoxene as the result of the decomposition of ilmenite. Secondary iron oxide in the form of minute irregular patches can be observed in all the sections; in much decomposed specimens earthy limonite frequently occurs as the material filling the vesicles which have been exposed to surface weathering. White mica in small flakes and a fine mosaic of a colourless mineral occur in the decomposed felspar. Kaolin as a decomposition product of felspar is especially well developed in the rock of Down's Hill quarry. The section in this exposure showed at the east end a compact, grey, amygdaloidal rock with phenocrysts of felspar, becoming more vesicular towards the west. The rock is cut by almost vertical faults, along one of which a development of kaolin occurred, forming a highly cleaved white flaky mass a few inches in thickness and stained in parts with iron. It seemed to be a final stage of decomposition of the rock, which is very rich in felspar.

Calcite is conspicuously absent in these rocks, except in the cases where they overlie limestone bands, as at the old quarry near Tuckenhay. Its absence as a decomposition product of felspar gives further support to the view that the felspar is not of a very basic species.

Summary of the Decomposition of the Diabases.

All the diabases of the Ashprington area are intensely altered; the modifications which the rocks have undergone have resulted in three types of change.

(1) Mineralogical alteration by which the original constituents of the rock have been replaced by secondary minerals.

(2) Mechanical modification which caused the breaking and deformation of the minerals and the development of cleavage planes in the rocks.

(3) The disintegration of the rocks by weathering agencies. As a result of the mineralogical alteration the felspar was replaced by chlorite, epidote, muscovite, quartz, some kaolin, and possibly in some cases by calcite. These alteration products often show evidence of being developed before the rocks were modified by pressure to which this area was subjected, and probably at an early stage in their history.

As a result of pressure the rocks became folded, faulted, and cleaved. The veins were crumpled, strain shadows were developed in the quartz in the veins, amygdales were elongated and flattened, and felspar and augite crystals broken. The chlorite patches also were elongated and lost any definite outline they may originally have possessed. Very little mineral development seems to have taken place at this stage of alteration.

A further effect of mechanical deformation is shown in the scoriaceous basalt from Eaglewood quarry, which is dark purple in colour and much cleaved; it passes into a purplish-red slate, with greenish and whitish patches on the cleavage surfaces. Rocks of this character are common throughout the district, and, no doubt, many of them have originated in this way, although no other exposure than the one quoted showed proof of this.

The last stage of decomposition is that caused by weathering agencies which split up decomposed rocks along the cleavage planes and oxidize the irony material to minute grains of limonite and hæmatite, giving the characteristic red and brown colour to the soil and much decomposed rocks.

(2) *Fragmental Rocks.*

A certain number of undoubted fragmental rocks can be identified in this area, although many of the much altered rocks cannot be definitely determined as clastic or igneous. The undoubted fragmental rocks differ in coarseness, but the recognizable fragments in all cases are mainly of felspar. In addition, some of the tuffs contain rock fragments and remains of basic lapilli.

The felspars are often broken and always decomposed. In the case of the tuff collected from the quarry behind Crowdy's corn mill (XXIX), the felspars could be identified as oligoclase. Aggregates of crystalline calcite are often abundant in the tuffs, and as a rule no organic structure is traceable; but in the ash from this quarry one of the calcite patches showed distinctly the typical structure of a fragment of an echinoderm.

Lapilli do not occur in the specimens collected from the main Ashprington area, but are shown in a section from a loose specimen found on a hill near Eight Acre Pens, Linhay. This is the locality referred to in the Torquay Memoir (p. 73) as occupied by a coarse volcanic tuff surrounding a probable volcanic neck. The outlines of the lapilli, which are roughly elliptical, have become very indistinct. In them the groundmass is a colourless devitrified glass, and contains

numerous small amygdales filled with chlorite. Similar tuffs containing lapilli have been collected on the western borders of the area from an old quarry south of Harberton, and also from quarries east of North Huish church and south of Diptford.

Rock fragments are abundant in the rock exposed in the hedge near Austin's Close (see Fig. 2, p. 353). When examined microscopically they show structure characteristic of basalts, and in some, fine ophitic structure is recognizable in the groundmass. Small decomposed phenocrysts of felspar, rectangular, lath-shaped or rhombic in section are abundant, and often show a roughly parallel orientation indicative of flow. Amygdales are common, small, irregular in outline, and mostly filled with a fine quartz mosaic. Calcite patches occur, which sometimes fill the amygdales, and are sometimes associated with the decomposed felspar. One of the fragments contained two xenocrysts of felspar; their angles are rounded, and two concentric zones of mineral development occur at the margin; an outer of felspar and actinolite and an inner rich in chlorite and iron oxide granules. The felspar is decomposed and contains chlorite and a few actinolite needles. A similar large felspar is found in one of the sections cut from the rock from the copse south-east of Austin's Close. Numerous fine veins of quartz cross the rock, and patches of quartz mosaic associated with chlorite show rectangular and rhombic shape and evidently replace some of the felspar phenocrysts. The silica percentage of one of the fragments was determined as 59·6, and the specific gravity as 2·68.

From these facts it is clear that, although the structure of the rock fragments is that characteristic of basalts, the silica percentage and the specific gravity are typical of less basic rocks. It seems, therefore, from the consideration of chemical composition and petrological characters, that the fragments are of basalts which have undergone subsequent silicification. In structure the fragments closely resemble the unsilicified rock from the copse to the south-east of Austin's Close, from which they are possibly derived. The matrix of the tuff in which the fragments are imbedded consists mainly of broken felspar and chloritic material and an abundance of fine granular epidote.

4. Summary.

The foregoing description makes it clear that the rocks of the Ashprington area closely resemble the spilites and schalsteins of Upper Devonian age in the Plymouth district, described in the Plymouth and Liskeard Memoir (p. 94 et seq.), but the diabases of the former differ from the spilites of the latter in having fine-grained ophitic structure and in the prevalence of felspar phenocrysts.

No example of coarser intrusive ophitic rock or proterobase such as is described by Dr. Flett in the Survey memoir mentioned above is met with in the Ashprington area. The sub-ophitic rock exposed at Stancombe Linhay and Eaglewood quarries approaches most closely to the ophitic type. North Huish and Diptford to the west of the area (Ivybridge and Modbury Memoir, p. 78) are the nearest localities at which coarse ophitic rock is exposed.

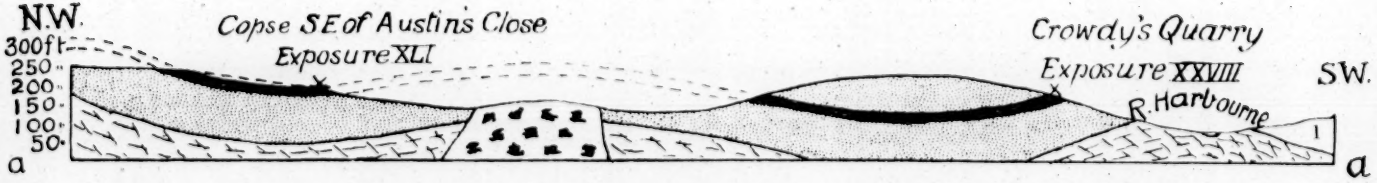


FIG. 3.—SECTION ALONG THE LINE *a*—*a* IN MAP 1. Scale 10·5 inches = 1 mile (approx.).

[1] This blank place should be stippled as "finer volcanic ash".

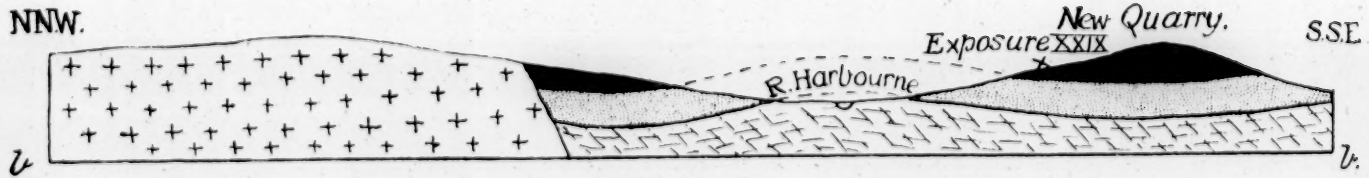


FIG. 4.—SECTION ALONG THE LINE *b*—*b* IN MAP 1. Scale 10·5 inches = 1 mile (approx.).

The key to the symbols for Figs. 3 and 4 is the same as for Fig. 1.

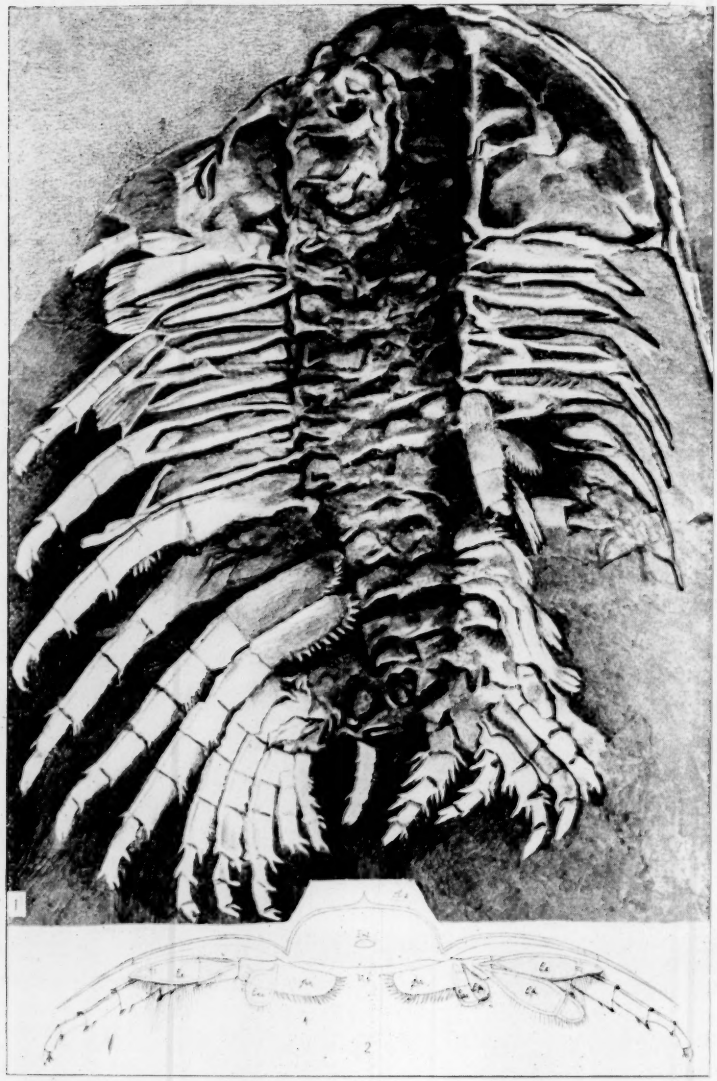
The petrological characters of all the specimens of diabase collected from the exposures in the area east of Harbertonford, with the exception of that from Austin's Close, are similar. They are fine-grained and porphyritic, showing only such variations as might be found in different parts of the same lava. Thus the rocks show more marked flow structure in some parts than in others, variation in the coarseness of the ophitic structure, and slightly different degrees of decomposition. In the exposures at "New quarry" and Crowdy's quarry the diabase is evidently a lava flow interbedded with ashes, and from the resemblance of the petrological characters of these rocks to those of the old quarry and of the copse south-east of Austin's Close, it can be inferred that the last two exposures are of the same lava-flow. The dip of the beds is gentle and all the outcrops of diabase occur either just above or just below the 200 feet level.

The diabase of Austin's Close differs from the other specimens. It shows no trace of original ophitic structure, and the phenocrysts of felspar are large and well-shaped, although much decomposed and with rounded angles; they have no definite arrangement. The rock seems to have been more resistant to the pressure which affected the district; cleavage is not so marked, and the felspars, though often deformed and cracked, are not so distorted and drawn out as those in more cleaved diabases. These facts suggest that this rock was not part of the same lava-flow but originated as a small intrusion shown at N.N.W. in Fig. 4. No junctions with the neighbouring rocks could be found, so that direct evidence was not available.

The limited extent of the coarse fragmental rock, the size of the included fragments and their silicification, which is doubtless due to the action of vapours connected with volcanic action, leads to the conclusion that this rock occupies the position of a small parasitic vent (see Fig. 3). Similar vents were probably numerous in the Ashprington area, and if so, this would account for the extensive development of the volcanic rocks in this district.

We have, therefore, near Harbertonford, evidence of a lava-flow, a great preponderance of ash, a small vent and a small intrusive mass. This is probably typical of the occurrence and origin of the spilitic volcanic rocks in the larger Ashprington area, whose development was initiated early in the Devonian period in a district that was undergoing gentle subsidence. Thus these rocks give an additional illustration of the view expressed by H. Dewey and Dr. Flett,[1] and more recently by Dr. A. Harker,[2] as to the connection between the petrological characters of the spilites and the conditions under which they were formed.

[1] Geol. Mag., 1911, p. 246.
[2] Quart. Journ. Geol. Soc., vol. lxxiii, p. lxxxviii, 1917.



C. D. Walcott.

NEOLENUS SERRATUS (Rominger). Burgess Shale (Middle Cambrian). British Columbia. (From Walcott.)

III.—Dr. C. D. Walcott's Researches on the Appendages of Trilobites.

By Dr. W. T. Calman, D.Sc., F.Z.S.,
of the British Museum (Natural History).

[Dr. C. D. Walcott. Cambrian Geology and Paleontology, IV, No. 4: Appendages of Trilobites. Smithsonian Miscellaneous Collections, vol. lxvii, No. 4, Washington, December, 1918, pp. 115–216 + Index, pls. xiv–xlii, text-figs. 1–3.]

(PLATE VIII AND TEXT-FIG. 1.[1])

IT is nearly forty years since Walcott published the well-known memoir which first gave palæontologists definite information regarding the appendages of Trilobites. This work was based on a laborious investigation of *Calymene senaria* and some other species by means of thin sections. Since then much knowledge has been gained, and, in particular, Beecher's researches on *Triarthrus* have provided us with a new conception of the Trilobite limb which, in some respects, is not readily to be reconciled with Walcott's earlier results. Now, at length, in this finely illustrated monograph, the veteran student of the Trilobita brings together the results of his own work and that of other investigators and reviews the whole in the light of his unrivalled experience.

In all, eleven species are dealt with, and restorations are given of *Calymene senaria*, *Triarthrus becki*, and *Neolenus serratus*, the three species of which the structure is most fully known. The last-named species is represented by finely preserved specimens in the Burgess shale (Middle Cambrian) of British Columbia, from which Dr. Walcott has described so many novel forms of animal life in recent years.

By the kindness of Dr. Walcott we are able to reproduce two of his figures illustrating *Neolenus* (see Plate VIII and Text-fig. 1). It will be seen from the restorations that the limbs are of some complexity. The jointed and spinous leg (endopodite) has a strong basal segment, produced inwards as a toothed gnathobase, to which are attached as many as four lobular appendages. One of these, distinguished by the marginal fringe of long setæ, is identified as the exopodite, and two others, one large and one smaller, are lettered as epipodites. Another small lobe is called an "exite", but as it is stated to be "probably attached to the inner side of the protopodite" the name is hardly well chosen. The most remarkable feature of the species, however, is the presence of a pair of long multiarticulate caudal filaments resembling those of *Apus*. Nothing like these has hitherto been seen in any Trilobite (Text-fig. 1, *c.r.*, p. 360).

In the case of *Triarthrus* the modifications which Dr. Walcott finds it necessary to make on Beecher's well-known restoration are mostly of a minor kind. The chief is the addition of a series of small leaf-like epipodites attached to the bases of the limbs. The fringes of the exopodites were described by Beecher as made up of "narrow, oblique, lamellar elements", and he suggested that they may have served as gills. The photographs now given

[1] The original illustrations have been kindly lent by Professor C. D. Walcott.

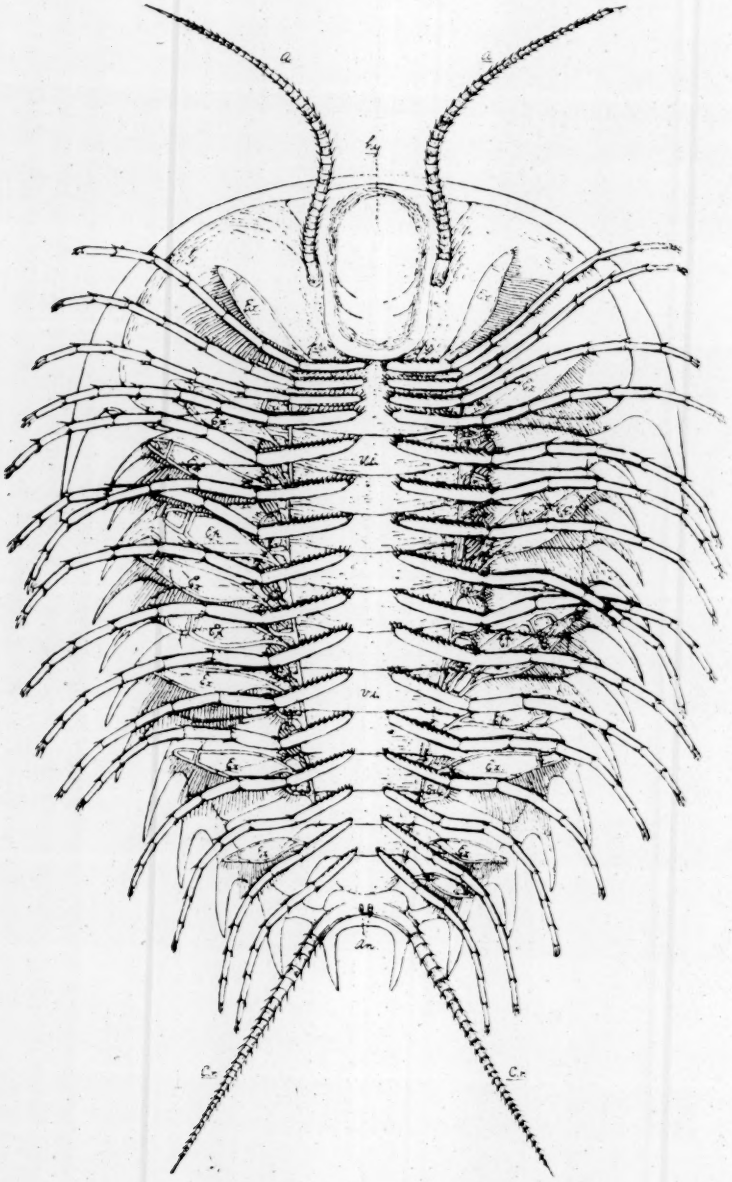


FIG. 1.—*Neolenus serratus* (Rominger).

Restoration of the ventral aspect with appendages. Burgess Shale (Middle Cambrian), British Columbia. (From Walcott.) *hy.* hypostome; *a.* antennules; *an.* anus; *c.r.* caudal rami; *ep.* epipodite; *ex.* exopodite; *pr.* gnathobasic process of protopodite; *v.i.* ventral integument.

show some resemblance to the pectines of scorpions, and at all events the form of the elements is very different from that usually indicated by the term "setæ" which is here applied to them. Dr. Walcott attaches considerable importance to his conclusion that the limbs of the pygidium had long and slender endopodites like those of the middle region of the body, and that the lobate, phyllopod-like elements described by Beecher should be referred to the exopodite. The photographs illustrating this point, however, are not sufficiently clear to be quite conclusive.

The revised restoration of *Calymene* now given differs in some important details from that published in 1881. Dr. Walcott has re-examined the material on which his earlier work was done, and reproduces some of his figures alongside of photographs of the sections from which they were drawn. As now interpreted, all the limbs are provided with large gnathobases like those of *Triarthrus* and *Neolenus*. In addition to the bifid spirally coiled appendage, now called the exopodite, all the limbs bear a curiously shaped epipodite with a terminal fringe of setæ. Dr. Walcott maintains his opinion that the two branches of the so-called exopodite were of the spirally coiled form which he originally described, rejecting the suggestion that the appearances seen in his sections resulted from the cutting across of fringes of obliquely-set lamellæ like those on the exopodites of *Triarthrus*. His conclusions are not to be lightly disputed by anyone who has not studied the actual specimens, but some doubt must remain so long as these spiral appendages have only been seen in the species examined by the method of section-cutting, and not in any of the forms in which the appendages are displayed in surface view. Evidence has now been obtained that this species had filiform antennules like those of *Triarthrus* and *Neolenus*, and they are included in the restoration.

On the much-discussed question of the affinities of the Trilobites, Dr. Walcott unhesitatingly decides for their association with the Crustacea, and against the view that they were related to the Xiphosura and Arachnida. He does not discuss the reasons for this conclusion in any great detail, and it may be suggested that in the comparisons brought forward he hardly makes sufficient allowance for the very wide range of structure in the Crustacea. Thus, for example, it is only with large reserves and qualifications that the resemblances of the Trilobite limb to the thoracic legs of *Anaspides* can be regarded as supporting the previous comparison with *Apus*, while it may be stated with some confidence that the sessile eyes of *Koonunga* have nothing whatever to do with the fact that the eyes of Trilobites are also sessile. Before such comparison can be profitably entered upon it is essential to have a clear conception of the classification and phylogenetic relations of the main divisions of the Crustacea, and on this point Dr. Walcott has not availed himself of the most recent information. He quotes, apparently with approval, Beecher's arrangement of the Trilobita "as a sub-class of the Crustacea, equivalent to the sub-class Entomostraca and to the third sub-class Malacostraca". Now it

is true that many writers even at the present day adopt the classification of Crustacea into the two sub-classes Entomostraca and Malacostraca, but this is due merely to the inertia of tradition. The "Entomostraca" have no more claim to constitute a taxonomic unity than have the "Invertebrata". The groups included under the name, the Branchiopoda, Ostracoda, Copepoda, and Cirripedia, are no more closely related to one another than any one of them is to the Malacostraca, and they should be treated as equivalent sub-classes of the Crustacea. When they are arranged in this fashion it becomes clear that the Branchiopoda are the only sub-class that can be regarded as having any direct relationship with the Trilobites. Each of the other sub-classes has attained to a more or less strictly defined number of trunk-somites and appendages. Only the Branchiopoda, like the Trilobita, are, to use Lankester's term, *anomomeristic*. The Malacostraca, in addition, have the trunk appendages grouped in the two sharply defined "tagmata" belonging to the thorax and abdomen. The Ostracoda, Copepoda, and Cirripedia are, in different ways, highly specialized groups, and the only characters which can be usefully considered in comparing them with Trilobites are those that may be supposed to be inherited from the common stock of Crustacea. Thus, it is legitimate to supplement a comparison of the Trilobites with the Notostraca (*Apus*) by a reference to the more generalized mouth-parts (biramous mandible-palp, etc.) of certain Copepods.

One of the pieces of evidence that has influenced opinion most strongly in favour of the Crustacean affinities of the Trilobites is afforded by Beecher's determination of the number of cephalic appendages in *Triarthrus*. Behind the preoral antennules, he found four pairs of appendages, each biramous and provided with a gnathobase. Since the antennæ of Crustacea are still postoral and carry a masticatory process or gnathobase in the nauplius larva, the correspondence of the postoral cephalic appendages of *Triarthrus* with antennæ, mandibles, maxillulæ, and maxillæ seems to be complete. In view of the great importance of this correspondence it is much to be regretted that it has not been possible to confirm it in any of the other species of Trilobites. Dr. Walcott, indeed, repeatedly refers to four pairs of cephalic legs, but it is not clear that the precise number could be determined in any case without reference to the analogy of *Triarthrus*.

The biramous form of the limbs in *Triarthrus* has been regarded, with justice, as one of the main supports of Crustacean affinity. The objection that the protopodite, to which the two rami are attached, appears to be unsegmented, while in the Crustacea it is usually composed of two, sometimes of three segments, need not be regarded as insurmountable. Dr. Walcott definitely describes the protopodite of the Trilobites as "consisting of a fused coxopodite and basopodite", but this would appear to be rather a probable inference than an observed fact.

The discovery of a pair of multiarticulate caudal filaments in *Neolenus* is a new and weighty piece of evidence in favour of affinity with Crustacea. In one form or another a caudal furca is found in

all the main divisions of the Crustacean stock, and the rami are filiform and multiarticulate not only in the Notostraca (*Apus*, etc.) but also in certain Cirripedes. Nothing of the kind is found in any of the Arachnidan groups.

While giving due weight to these and other evidences of Crustacean affinity, it is important not to lose sight of the characters, some of them of considerable weight, in which the Trilobita differ from what we must suppose the primitive Crustacean to have been like. One of the most important is the absence of a carapace. In the Crustacea the carapace is formed by a fold of the dorsal integument arising from the hind margin of the head-region, enveloping and sometimes coalescing with more or fewer of the body-somites. Only in the Anostracous Branchiopoda, in some Syncarida (*Bathynella*), and possibly in the Copepoda, is this shell-fold entirely absent, and it is a reasonable conclusion that it must have been present in the ancestral stock of the Crustacea. No Trilobite shows any trace of such a fold.

The sessile eyes of the Trilobites may perhaps be reckoned as another non-Crustacean character. Sessile eyes are indeed common enough among recent Crustacea, but there are good reasons for thinking that the condition is in all cases a secondary specialization and that the eyes were primitively pedunculate and movable. Even the sessile eyes of the Notostraca and Conchostraca, which are movable and covered by an invagination of the integument, are regarded, with considerable probability, as derived from stalked eyes. In the Trilobita we have no evidence that the eyes were ever movably pedunculate, although the suggestion has been made that the eye-bearing "free cheeks" may have been formed by the expansion of ocular peduncles.

Finally, it is to be noted that the exopodites of *Triarthrus* with their fringe of lamellar elements, possibly branchial in function, are something very different from the "setiferous exopodites" of many Crustacea with which they have been compared. It is possible that we have here a hint as to the origin of the "gill-books" of *Limulus*.

No Trilobite yet discovered is so generalized that it could be regarded as standing in the direct line of descent of either Crustacea or Arachnida, but the group as a whole seems to point the way towards some form that may have been the common ancestor of both. Dr. Walcott's wonderful discoveries in the Burgess shale give hope of further progress in tracing the phylogeny of the primitive Arthropods, and the fuller investigation which he promises of the remarkable *Marrella* will be awaited with much interest.

EXPLANATION OF PLATE VIII.

FIG. 1.—*Neolenus serratus* (Rominger). Burgess Shale (Middle Cambrian), British Columbia. (From Walcott.) Specimen displaying the ventral surface with the appendages *in situ*. At the posterior end of the body a portion of one of the caudal rami is visible. (From a retouched photograph, $\times 1\frac{1}{2}$.)

,, 2.—Diagram of a transverse section of the body. *d.s.* dorsal shield; *ep.* epipodite; *ex.* exopodite; *exi.* exite; *int.* intestinal canal; *pr.* gnathobasic process of protopodite; *v.i.* ventral integument.

IV.—The Two Magmas of Strathbogie and Lower Banffshire.

By H. H. Read, H.M. Geological Survey, Scotland.

THE field-work upon which this communication is based was carried out in 1917 and 1918, in preparation for the Geological Survey map of Sheet 86 (Huntly).

In the Strathbogie district of Aberdeenshire and in Lower Banffshire[1] two series of igneous rocks have a wide distribution. The earlier of these series was intruded prior to the movements which caused the foliation and schistosity of the Dalradian sediments, the later after these movements had ceased. The object of this paper is to detail the diversity of original rock types constituting the Older Series, to delineate their magmatic sequence, and to compare them, both in order of intrusion and in petrographic characters, with the similarly diversified Younger Series.

1. The Older Series.

Igneous rocks of prefoliation age have a wide distribution in this district, as will be seen from the Sketch-map. These Older rocks are mostly altered to serpentine, tremolitic serpentine, epidiorite, amphibolite, hornblende-schist, and augen-gneiss, but it has been found possible to trace back the serpentines to pyroxene and olivine rocks, the epidiorite, amphibolite, and hornblende-schist to gabbro and enstatite gabbro, and the augen-gneiss to granite. The most important locality of the Older Series from this point of view is that of Portsoy, Banffshire. The rocks of this locality have been described many years ago by Jameson,[2] Cunningham,[3] and Heddle.[4]

The non-felspathic ultrabasic members of the Older Series are usually in the condition of serpentine, occasionally well foliated but more often massive. Throughout the district, however, rocks composed wholly of monoclinic pyroxene are strongly developed and can be found in all stages of transformation to serpentinous and tremolitic derivatives. Such anchi-monomineralic rocks form independent intrusions, and since they are cut by epidiorite may be considered as the earliest manifestation of the Older igneous activity. Type localities are at Portsoy, at Whitehill west of Rothiemay Station, and on both flanks of Evron Hill. The pyroxenite is a coarse massive greenish-grey non-foliated rock which in thin slice is seen to consist of large interlocking crystal plates of a pale-coloured augite. No felspar has been seen in the rock. Occasionally olivine in small grains is scattered sporadically throughout the rock and may have been locally predominant. Enstatite and hornblende, probably primary, also occur at certain localities. There is never any banding of the constituents, collection of olivine in layers or fluxional arrangements of the

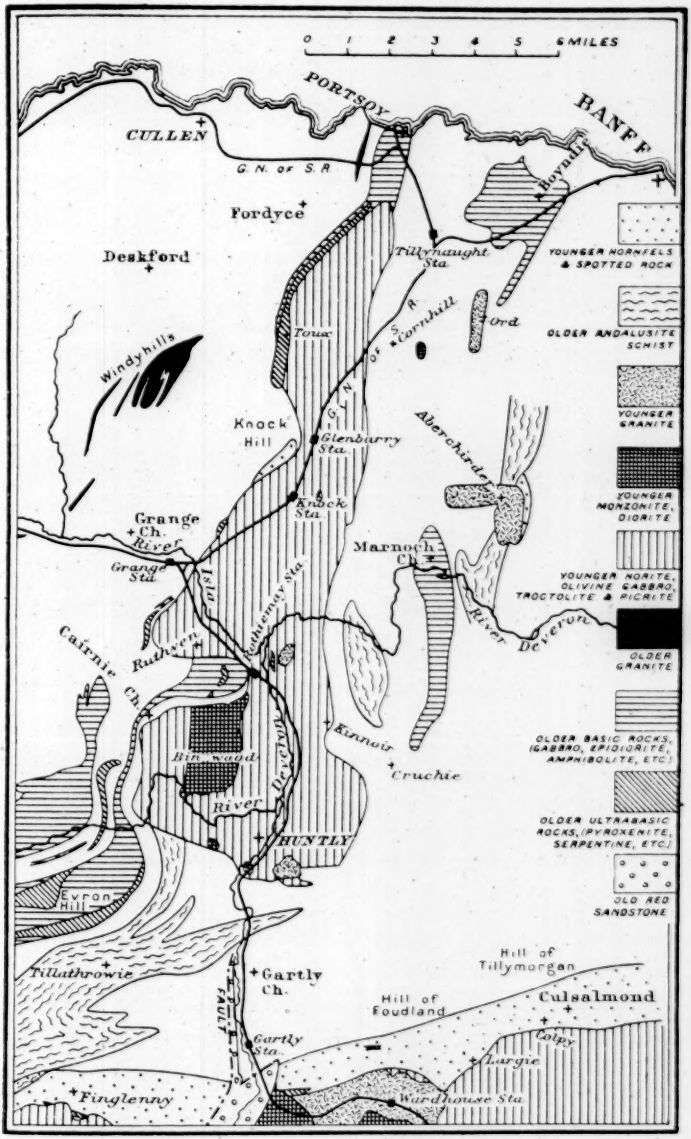
[1] Further notes on these districts will appear in the *Summary of Progress of the Geological Survey of Great Britain for 1918*.

[2] R. Jameson, *Mineralogy of the Scottish Isles, etc.*, 1800, vol. ii. p. 270 et seq.

[3] Hay Cunningham, "Geognostic Account of Banffshire": Trans. High. and Agric. Soc. Scot., ser. II. vol. viii. p. 447, 1842.

[4] M. F. Heddle, "Chapters on the Mineralogy of Scotland": Trans. Roy. Soc. Edin., vols. xxvii–xxix, 1876–80.

crystals. The position of such pyroxenite masses as are associated with epidiorites, etc., seems in no case due to gravitative differentiation. These pyroxenites by their alteration produce



Sketch-map, showing distribution of Older and Younger Igneous Rocks in Strathbogie and Lower Banffshire.

a mixture of tremolite and serpentine, and in the olivine-rich types homogeneous serpentine usually results. The tremolite of the pyroxene rocks has been developed under pressure from the solid augite, the large crystals of which are crushed and distorted, the amount of tremolite present being in intimate relation to the degree of crushing suffered by the rock.

At Portsoy a second independent intrusion of a monomineralic rock is furnished by a small mass of anorthosite. This coarse-grained greenish-grey rock is composed almost entirely of labradorite felspar in crushed augen between excessively fine-grained cataclastic granules of similar felspar. Scarce chlorite, rare epidote, and talc complete the rock. This anorthosite is undoubtedly an independent intrusive mass, and is against Dalradian limestone and schist on one side and a pyroxenite on the other.

The great majority of Older basic rocks is derived from a gabbro which is found well preserved at Portsoy. This parent rock of the epidiorites and amphibolites is a coarse gabbro composed of labradorite, augite, apatite, and iron oxides, with secondary hornblende and biotite. The rather elongated crystals of labradorite are saussuritized and slightly crushed. The ophitic augite is marginally altered to the fibrous or compact hornblende of the epidiorites.

Primary modifications of this gabbro are common, but form only local variations in the gabbro mass. By the dwindling of the felspar content and by the incoming of olivine, a rock is formed in which the original constituents were olivine, diallage, and scarce labradorite. The olivine, now entirely replaced by pilitic tremolite, quartz, chalcedony, and carbonates, formed rounded grains poikilitic in large diallage plates which are in process of alteration to hornblende and biotite. The felspar is a scarce rather fresh basic plagioclase. Compound reaction rims between the olivine and felspar are occasionally developed and are exactly similar to those found in certain types of the Younger Series. The rock is occasionally crushed.

In the Burn of Durn at Portsoy an enstatite gabbro is found in which a colourless enstatite is predominant over the monoclinic pyroxene. Both species of pyroxene are partially or completely altered to a pale-green hornblende, and cataclastic effects are common in the plagioclases.

Bands and streaks of a rock more acid than the predominant type are found in the gabbro of Portsoy. Such dioritic types are composed of a medium plagioclase, quartz, and biotite.

Primary banding is common in the Portsoy gabbro. This is of two types, the first being formed by alternations of two rocks, the second by alternations of two minerals. The first type consists of bands of a labradorite rock with a little hornblende secondary from pyroxene, alternating with bands of hornblendic (originally pyroxenic) rock with subordinate plagioclase. This complementary banding is undoubtedly original. Those rocks to which the name gabbro schist may be applied show a delicate banding of light coloured saussuritized labradorite and of dark secondary hornblende enclosing augen of diallage. This banding is due to movement

during consolidation, and the effect of the subsequent cataclasis has been to emphasize the banded nature of the rock, which in structure then resembles the foliated gabbro described and figured by Teall.[1] All banding is parallel to the stress lines of the country.

The olivine-pyroxene-felspar rock, enstatite-gabbro, diorite, and banded gabbros do not form independent intrusions, but are small parts of a heterogeneous intrusion whose predominant member is ordinary gabbro. No differentiation in place can be demonstrated and it is considered that this heterogeneity is due to differentiation before intrusion. All the varieties of the gabbro pass into epidiorites by the complete replacement of their pyroxene by secondary hornblende. From the epidiorites are derived the widespread amphibolites by a still more abundant development of secondary hornblende and the concomitant recrystallization of the original labradorite into a mosaic of clear acid plagioclase. These two types, displaying no marked foliation, are predominant in the Older basic series as now found. By the development of cataclastic foliation the hornblende-schists are produced.

The acid members of the Older Series are exemplified by the augen-gneisses of Portsoy and Windyhills. In these rocks large lens-shaped patches of microcline and orthoclase, with subordinate oligoclase, are set in a cataclastic groundmass of granular quartz and felspar with shreds of primary biotite, and much secondary muscovite along shear planes. The original rock was a biotite microcline granite.

The magmatic sequence of the Older Series is, as usual, one of decreasing basicity or of increasing alkalinity. The main magma was largely gabbroic in nature and has been intruded as a heterogeneous magma due to differentiation in a lower basin, and now displays the varied types of predominant gabbro, scarce olivine-pyroxene-felspar rock, scarce enstatite-gabbro, scarce diorite, with banded felspathic and pyroxenic portions. The manner of differentiation cannot be stated, but no degree of differentiation in situ has taken place. The anchi-monomineralic rocks are earlier than the gabbro; one of these independent intrusions is composed of the femic constituents, the other of the felspathic constituent of the original gabbroic magma from which they have split. The acid differentiate is quite late and consists of an alkali-granite. The areal relations for this district of the three divisions are ultrabasic rocks 2·6 square miles, basic 15·6 square miles, and acid 1·55 square miles. The basic rocks are much cut out by the Younger Series, and the area formerly occupied by them may be approximately double that given above.

The Older Series must be considered with regard to Dr. N. L. Bowen's[2] recent work on differentiation by the sorting and collection of crystals in a crystallizing magma. At Portsoy among the Older

[1] J. J. H. Teall, GEOL. MAG., 1886, Pl. XIII, p. 481; *British Petrography*, 1888, pls. xxvi, xliii.

[2] N. L. Bowen, "The Last Stages in the Evolution of the Igneous Rocks": *Journal of Geology*, vol. xxiii, supplement, pp. 1–91, 1915. "The Problem of the Anorthosites": ibid., vol. xxv, p. 209, 1917.

Series, and as will be seen later at Huntly among the Younger Series, it can be shown that differentiation has not taken place in situ. The absence of gravitative separation and of continuous variation and the presence of independent monomineralic intrusions point to the conclusion that differentiation took place in a lower magma basin. The main intrusion was undoubtedly one of a heterogeneous,[1] predominantly gabbroic, magma, and from this magma had already been separated off the two monomineralic types —pyroxenite and anorthosite. On Bowen's theory, such separation of monomineralic types would be by the collection of masses of crystals of pyroxene and of labradorite, and therefore, if such monomineralic rocks were intruded as independent masses, their origin would be demonstrated by cataclastic structures. Such structures are, of course, apparent in the monomineralic rocks of Portsoy, but these rocks were affected by the regional folding and, in common with all the igneous rocks of the Older Series, show evidences of crushing stresses. How, then, are these crush effects due to later folding to be distinguished from those due to intrusion as a mass of crystals? Orientation of crystal plates has never been seen in the massive pyroxenites of this series, there is no segregation of olivine into layers, and the crystals of pyroxene form interlocking junctions. The sporadic olivine is often interstitial to the pyroxene. In the author's opinion, the crushing seen in the pyroxenite is best explained as due to the effects of regional folding on a solid and cold rock. Similarly the crushing of the anorthosite is exactly like that of the augen-gneisses. Until further knowledge is obtainable concerning the immiscibility of silicate magmas,[2] especially under pressure, and also concerning the role of mineralizers, particularly of magmatic water, in ultrabasic rocks, the question of the origin of the monomineralic rocks of the Older Series must be left open. On the whole, however, the writer considers some kind of separation of a magma into liquid phases to be demanded by the field relations of the Older Series of this district. Such a separation of liquid phases would be afforded by the operation of liquid immiscibility, or by the refusion of a solidified magma basin already differentiated, perhaps by crystallization. Such a refusion was postulated by Martin Schweig[3] and has lately been favoured by Dr. Harker,[4] but the cause of the rise in the isogeotherms evoked by the latter is unexplained. Liquid immiscibility, therefore, until proved impossible, should be considered as a process probably effective in magmatic differentiation.

2. The Younger Series.

The Younger Series of the Strathbogie district forms an elongated mass with a north and south trend, a direction parallel to the

[1] Cf. Geikie & Teall, "On the Banded Nature of some Tertiary Gabbros in the Isle of Skye": Q.J.G.S., vol. l, p. 656, 1894.

[2] Cf. R. A. Daly, *Igneous Rocks and their Origin*, 1914, pp. 225, 226. "Genesis of Alkaline Rocks": *Journ. Geol.*, vol. xxvi, pp. 123, 124, 1918.

[3] M. Schweig, "Untersuchungen über Differentiation der Magmen": Neues Jahrbuch, Beil. Bd. xvii, p. 563, 1903.

[4] A. Harker, "Differentiation in Intercrustal Magma Basins": *Journ. Geol.*, vol. xxiv, p. 556, 1916.

foliation of the country. The younger igneous rocks of the Wardhouse district will not be considered here. That part of the Huntly Mass which occupies the district around Huntly has been described in detail by W. R. Watt,[1] but the whole of the area shown in the Sketch-map has been mapped by the present writer. The rocks of the Huntly Mass, with its isolated granite bosses of Aberchirder, Ord, and Longmanhill (4 miles E.S.E. of Banff), form a lengthy sequence, here appended in order of intrusion:—

1. Picrite-Norite Set (Picrite, Olivine-gabbro, Troctolite, Norite).
2. Diorite of Gibstone.
3. Monzonite and Diorite (Central Intrusion of W. R. Watt).
4. Granite.
5. Pegmatites with tourmaline.

The picrite-norite set are well seen around Huntly and extend thence northwards to within two miles of Portsoy. The picrite forms a narrow border on the western edge of the Huntly Mass in the Huntly district. It is a black rock with conspicuous lustre mottling and in thin slice is rather variable. Occasionally it approximates to a peridotite, but usually carries common ophitic pyroxene with relatively scarce basic plagioclase. Brown hornblende, biotite, and hypersthene occur in small amount. The olivines are slightly serpentinized. No trace of cataclastic structure is found. The olivine-gabbro occurs east of the picrite and forms a coarse very fresh rock with labradorite, olivine, and pyroxene, with subordinate brown hornblende and biotite. The troctolitic type occurs mainly east of the olivine gabbro and is a characteristic olivine-labradorite rock with beautiful fluxional arrangements of the felspars and with banding of more basic types of peridotite, etc. These fluxion structures are parallel to the margin of the mass, as is usual amongst fluxional gabbros.[2] Such structures are best explained for the Huntly Mass as due to movement during the intrusion of a somewhat pasty and not strictly homogeneous magma. Troctolite also occurs at the western edge of the Huntly Mass west of Knock Station. Beautiful reaction rims of anthophyllite and actinolite are developed between the olivine and felspar of the troctolitic and olivine gabbros.[3] The predominant body of the picrite-norite set is, however, the norite. This type forms nine-tenths of the Huntly Mass. It is usually a fine-grained bluish rock, consisting of labradorite-bytownite and hypersthene with widespread augite, hornblende, biotite, and olivine. Structures are variable, being ophitic, granular, or granitic. Occasionally the norite lacks its hypersthene and then forms a very coarse gabbro.

The members of the series—picrite, olivine-gabbro, troctolite, norite—follow in order from west to east, and at first glance this arrangement seems to point to a direct gravitative differentiation of a gabbro magma in the position in which it is now found. But no

[1] W. R. Watt, "Geology of District around Huntly (Aberdeenshire)": Q.J.G.S., vol. lxx, pp. 266–93, 1914.

[2] F. F. Grout, "Internal Structures of Igneous Rocks": *Journ. Geol.*, vol. xxvi, p. 439, 1918.

[3] W. R. Watt, loc. cit., pl. xxxviii, fig. 2.

gradual passage from one rock to another can be demonstrated and the individual rock types are well marked. Again, the west–east sequence in certain localities may be partly reversed. Moreover, there is no ultrabasic western border to the norite north of the Huntly district. It seems more probable that the differentiation of a gabbroic magma took place in a lower chamber and that the picrite was intruded as a small sill, followed by increasingly acid derivatives, each of which slid in roughly on the top of its forerunner. But most of the picrite-norite set were fluid at the time of intrusion of the whole series and so no marked contacts are seen; schlieren and banded types occur and mixed edges may have been formed locally. Finally, the phase of the picrite-norite set was ended by the widened sphere of sill-like intrusion, together with great cross-cutting, of the norite magma, and by the time of intrusion of this norite the more basic members were sufficiently solid to be cut by dyke-like apophyses of gabbro and norite. The areal relations of this set are: picrite ·83 sq. mile, olivine-gabbro ·39 sq. mile, troctolite 3·32 sq. miles, and norite 37·4 sq. miles.

After the composite intrusion of the picrite-norite set had finished, there were intruded a few small bosses of diorite (quartz, biotite, augite, andesine). Of these bosses, that at Gibstone (1½ miles N.W. of Huntly) has a marked foliation which is, however, not of cataclastic origin. This Gibstone diorite is intermediate in composition between the earlier norite and the later monzonite, and probably owes its foliation to its soft and hot nature at the time of the movements which caused the monzonite to present a markedly intrusive character to the norite.

The picrite-norite set was solid at the time of intrusion of the large monzonite mass of the Bin Wood (Central Intrusion of Watt[1]). This rock is a coarse garnetiferous monzonite which has produced great contact effects on the earlier norite.[2] It consists of orthoclase, plagioclase, augite, biotite, quartz, and garnet.

The next member of the Younger Series is of granitic nature and forms small masses, sometimes in the basic members and sometimes as isolated bosses, as shown on the Sketch-map. The rock is a grey granite composed of quartz, predominant microcline, orthoclase, scarce plagioclase, biotite, and scarce muscovite. It often shows a very rude fluxional structure. All the granites associated with the Huntly Mass are biotite-microcline granites.

Tourmaline pegmatites are common as the final stage in the intrusion of the Younger Series of the Huntly Mass.

The areal distribution of the whole Younger Series of this area is: ultrabasic ·83 sq. mile, basic 41 sq. miles, intermediate 2·8 sq. miles, and acid rocks 3·2 sq. miles.

Continuous variation in place is not seen in the Huntly Mass, and there seems to be an individuality about the various closely related types which is not explained by a crystallization-differentiation hypothesis.

[1] W. R. Watt, loc. cit., p. 275.
[2] W. R. Watt, loc. cit., pp. 282 ff.

3. The Two Series.

On comparing the two series of igneous rocks outlined above, it will be seen that there is a well-marked similarity in sequence and characters, but this similarity does not extend to details. The Older Series forms two anchi-monomineralic differentiates, one a femic type consisting of predominant pyroxene with subordinate olivine, the other of a felspathic type provided by the small anorthosite of Portsoy. The Younger Series has only a locally developed monomineralic phase, and its ultrabasic member is provided by a predominant olivine type with subordinant pyroxene and plagioclase, intrusion occurring before the production of a non-felspathic femic magma had been possible. So, felspar is common in the picrite of this series, but is never found in the pyroxene-olivine rocks of the Older Series. The basic members of the two series again present the same general types of gabbro, enstatite or hypersthene-gabbro, and diorite, but are different in the relative development of such types, in the predominance of certain species of pyroxene, and in the widespread occurrence of olivine in the Younger Series. The acid members are perfectly similar, both being biotite-microcline granites. The areal relations of the Older Series and of the Younger Series of the Huntly Mass show the same order of magnitude for the different differentiates of each series.

The distinction between the two series may be based upon the degree of alteration of the rocks, the character of this alteration among the Older Series, the characters of the predominant mineral in the ultrabasic facies, and the character of the pyroxenes in the two orthorhombic pyroxene-gabbros. In the field, the general greenish appearance due to the alteration into hornblende of the augite of the Older Series and the occurrence sooner or later of cataclastic foliation in them are of great value. Finally, a most important criterion is supplied by their metamorphic effects on the country rocks. The contact rocks produced by the Older Series are foliated by the later regional folding, whereas the effect of the intrusion of the Younger Series is to obliterate this foliation.

It may be stated, therefore, that in this district there are two petrogenic cycles separated by an epoch of great earth movement. Between Huntly and Portsoy the rocks of these two cycles have risen along almost the same belt of country and present great similarities in their main characteristics.

In conclusion, the author wishes to express his indebtedness to Dr. John Horne, F.R.S., and to Dr. J. S. Flett, F.R.S., for many helpful suggestions.

V.—Brachiopod Nomenclature: *Spirifer* and *Syringothyris*.

By J. Allan Thomson, M.A., D.Sc., F.G.S., Director of the Dominion Museum, Wellington, New Zealand.

According to a strict interpretation of the international rules of zoological nomenclature the generic name *Spirifer* is wrongly used for the group including *Anomites striatus*, Martin, and should be restricted to the group including *Anomites cuspidatus*, Martin,

i.e. it should replace *Syringothyris*, Winchell. My object in pointing this out is not to urge a strict interpretation of the international rules in this case, for it would serve no useful purpose to attempt to displace a name which through a century of usage has become the geological equivalent of a household word, but to show the need for geologists to combine with zoologists in demanding a list of *nomina conservanda* in zoology.

In 1814 or 1815 James Sowerby read a paper before the Linnean Society describing the presence of spiral coils in *Anomites striatus*, Martin, and proposing for it the genus *Spirifer*. He also stated that he suspected that *Anomites cuspidatus*, Martin, possessed similar coils. The substance of this paper became known not only in England but on the Continent, but the paper was not published until 1821.[1] In the meantime Sowerby published the genus in *Mineral Conchology*, vol. ii, 1818, pp. 41–43, Tab. 120, giving a diagnosis of the genus, followed by a description of *Spirifer cuspidatus*. Other species are mentioned, but none are named. King, Meek, and others have accepted *Anomites cuspidatus* as the type of *Spirifer*, but Davidson urged that Sowerby's intention that *Anomites striatus* should be the type must be accepted, and in this he has been followed by most subsequent authors, and *Anomites cuspidatus* has since been referred to the genus *Syringothyris*, Winchell, 1863. If *Anomites cuspidatus* is regarded as the type of *Spirifer*, *Syringothyris* becomes a synonym of *Spirifer*, while the group of *Anomites striatus* must take another name. Dall[2] sums up the position thus: If the work of restriction were to be done over again, it is probable that most authors would consider the rules of nomenclature better served by taking *cuspidatus* as the type, but the reverse process has been the rule among authors so long that it would be a serious detriment to science to attempt such a change at present.

Since the Fourth International Zoological Congress at Cambridge in 1898 there has been a Permanent International Commission on Zoological Nomenclature which studies questions of nomenclature and renders opinions upon cases submitted to it. Opinion 30[3] on Swainson's *Bird Genera* of 1827 almost exactly applies to the case of *Spirifer*. Swainson wrote and sent for publication to the *Zoological Journal* a paper containing diagnoses of several genera, with explicit designation of their types. This first written paper was unexpectedly long delayed in publication, greatly to the disappointment of the author, as he stated, who was powerless to prevent the inopportune delay. This paper was published in two

[1] *Fide* W. H. Dall, "Index to the Names which have been applied to the Subdivisions of the Class Brachiopoda": Bull. U.S. Mus., No. 8, 1877, p. 63. F. J. North ("On the Genus *Syringothyris*, Winchell": GEOL. MAG., Dec. V, Vol. X, pp. 393–401, 1913) gives the date of publication as 1818. I have not access to the publication in question, but all authors agree that it was published subsequently to *Min. Conch.*, vol. ii.

[2] Loc. cit.

[3] "Opinions rendered by the International Commission on Zoological Nomenclature." Opinions 30–7. SmithsonianIn stitution, Publication 2013, 1911, pp. 69–72.

parts appearing April–July, 1827, and August–November, 1827. In the meantime he described some new species of Mexican birds in a paper which appeared in the *Philosophical Magazine* in May and June, 1827, referring some of them to the new genera proposed in the earlier written but later published paper. The International Commission held that Swainson's bird genera in the *Philosophical Magazine* of 1827 are monotypic, and according to Article 30 (*c*) the species mentioned are types of their respective genera. Therefore, these types must take precedence over the designated types of Swainson which occurred later in the *Zoological Journal* of 1827. The argument on which this opinion was based was stated as follows:—

"In order to fully realize the bearing of the principle involved in the present case, let us ask ourselves the question: What was the type of these genera in the interim between the prior publication in the *Philosophical Magazine* and the type designation in the *Zoological Journal*? During these 'two or five months (as the case may be)' the genera rested solely on the generic name and the single species described in the *Philosophical Magazine*. No other species was known to belong to these genera during the two or five months. Surely during that period these generic names were monotypic, and could rightfully have no other type than the only species then described. But if a genus once has a rightful type there is no way under the international rules to substitute another later. If a genus has been monotypic for two or five months, or any other length of time, subsequent publication cannot alter its status however plausible may be the argument otherwise, and this status can be no more 'subject to change' than 'designation of the type' itself.

"Any interpretation other than the one here followed might give rise to serious complications. For instance, to admit that a later article can undo the types actually (though possibly unintentionally) published in an earlier article, as in this case, would make it possible for an author to publish a genus as monotypic and then, years later, to alter his type in some manuscript the publication of which had been purposely or unintentionally delayed for decades. Thus, unless an author definitely stated that a genus was monotypic, no genus originally published with mention of only one species could be looked upon as having the genotype definitely established until after the author's death, and after it was proved that he left no unpublished manuscript behind him."

The case of *Spirifer* is extremely similar but simpler. From 1818 to 1821 the genus was monotypic so far as Sowerby was concerned, and included only *Spirifer cuspidatus*, and this, therefore, cannot be displaced as the type of the genus if the international rules are to be adhered to.

Thanks to *Punch*, the name *Ichthyosaurus* has become a household word in a more complete sense than *Spirifer*, but it also can be used only in contravention of the international rules. It was proposed by Conybeare in 1821, but it is preoccupied by *Proteosaurus*, Home, 1819. Lydekker[1] stated the case thus: "There is no real

[1] R. Lydekker, *Cat. Foss. Rept. Brit. Mus.*, pt. ii, 1881, p. vii.

justification for superseding the earlier name *Proteosaurus* by the later *Ichthyosaurus*; but since the latter name has been universally adopted, the writer, after consultation with the Director of the (British) Museum, has come to the conclusion that this is one of the cases where an adherence to the rule of priority is not advisable."

An analogous case is furnished by the common mollusc, popularly known as *Octopus*. As a matter of fact *Octopus*, Lamark, 1798, is preceded by *Polypus*, Schneider, 1784, and in this case malacologists have applied the rule of priority and displaced *Octopus*,[1] but it may be doubted whether the interests of science are best served by such action.

These three cases, and doubtless many others which could be cited, show that a rigid application of the law of priority will displace names which by a century of usage have found their way into hundreds of textbooks, and even into popular literature. The best way to avoid so regrettable a step is for an International Zoological Congress to adopt a list of *nomina conservanda*. This paper is written to enlist the co-operation of geologists in creating a public opinion in this direction.

REVIEWS.

I.—Novitates Palæozoicæ.

Paleontologic Contributions from the New York State Museum. By Rudolf Ruedemann. N.Y. State Mus. Bulletin, No. 189. 226 pp., 36 pls. September, 1916.

THE belated appearance of this review must be excused by the War's delays, which hindered the receipt of the volume. It would, however, be a pity to pass over for that reason all the observations of interest that Dr. Ruedemann has here collected. Let us consider a few of them.

Plumalina plumaria, from sandy shales of the Portage group, described by J. Hall as a graptolite and referred by J. W. Dawson to the plant *Lycopodites*, is here said to possess no thecæ, but to have an inner solid carbonaceous (? chitinoid) axis and an outer granular (? calcareous) rind, comparable with the structure in the Gorgonidæ. The fossils are therefore referred provisionally to the Alcyonaria.

Another plant-like fossil, *Buthotrephis lesquereuxi*, from the Silurian Eurypterus beds, is found to consist of twisted thin tubes opening on the general surface in pores (about ·5 to 1 mm. linear), and is referred to *Inocaulis*, which Dr. Ruedemann regards as a graptolite allied to *Dictyonema*. Some species hitherto referred to *Dictyonema* (*D. furciferum* Rued., *D. cervicorne et alia* Wiman) are shown to have apertural processes with forked ends which attach themselves to the neighbouring branch, and so, while outwardly resembling the dissepiments of *Dictyonema*, differ from them in origin; they are placed in a new genus *Airograptus*, which should have been spelled

[1] e.g. H. Suter, *Manual of the New Zealand Mollusca*, Wellington, 1913, p. 1062.

Haerograptus. Dr. Ruedemann has previously described colonial stocks of various genera, but not of *Climacograptus*; he now figures a fine example of one in *C. parvus*.

The strangest fossil of the Portage beds was described in 1900 by Dr. J. M. Clarke under the name *Cryptophya* and referred by him to the echinoderms. Th. Fuchs (1905) suggested that it was the float of a siphonophore, and this view is strengthened by the recent discovery of specimens in which presumed air-chambers have been injected with sediment. A curious imprint from the same beds, on which a new genus *Plectodiscus* is here based, is probably a related form.

From the Glens Falls Limestone at the base of the Trenton, Dr. Ruedemann has obtained a *Pleurocystis*, the first found in New York State, and figures it as "*Pleurocystites squamosus* (Billings) mut. *matutina* nov." Why should Billings be in brackets, by the way? In the absence of a detailed description and measurements, one cannot say more than this: the fossils are certainly specifically distinct from *P. squamosa*, but closely resemble the Kentucky fossil *P. mercerensis* Miller & Gurley (not mentioned by Dr. Ruedemann) in all the characters that I have regarded as "specific" for this genus, as well as in the radiate sculpturing of the plates, a somewhat unusual feature. (See Trans. R. Soc. Edinburgh, 1913.)

The many valuable notes on Devonian Asteroidea, with their beautiful illustrations, may be left for Dr. W. K. Spencer to deal with. Here let us only state that they propose the new genera *Clarkeaster*, *Lepidasterina*, and *Klasmura*. There are also two new starfishes from the Silurian Conularia Limestones of Argentina, one an *Encrinaster*, the other serving as basis for a new genus, *Argentinaster*.

A curved, flattened, segmented body from the Marcellus shale, with overlapping scales on the concave margin, is certainly, as Dr. Ruedemann says, reminiscent of certain palæozoic fossils usually referred to the Cirripedia. He prefers, however, to regard it as a new species of *Protonympha* J. M. Clarke, which may be a polychætous annelid. Several annelid tubes from palæozoic rocks, apparently congeneric with *Serpulites longissimus* Murchison, are shown to spring from the adhesion discs which J. Hall described as *Sphenothallus* under the impression that they were plants. These fossils also present close resemblance to *Torellella* Holm, and a further link with the Conularida is thought to appear in *Conularia gracilis* Hall. Dr. Ruedemann therefore suggests that the Conularida may be derived from the Annelida.

The description of some new species of *Spathiocaris* revives the discussion about the Discinocarina. H. Woodward has considered them to be crustacean carapaces. Roemer and others took them for aptychi of goniatites. J. M. Clarke hesitates between a brachiopod, crustacean, and cephalopod connexion. Dr. Ruedemann now brings further arguments in support of their aptychus nature, though without fully satisfying even himself.

In some specimens of Lower Silurian age, Dr. Ruedemann recognizes the first American representatives of the doubtful fossils

which Barrande called *Anatifopsis*, and their study leads him to conclude that the genus should be placed in the Lepidocoleidæ. His description and figures are, however, far from convincing. For one thing, the ornament of his fossils differs in several respects from the growth-lines of both *Anatifopsis* and *Lepidocoleus*.

The description of some new Eurypterid remains leads Dr. Ruedemann to traverse the view of A. W. Grabau and Miss M. O'Connell that the Eurypterids always lived in rivers, and this he does to good effect.

The existence of eyes in the limuloid arachnid *Pseudoniscus*, of Silurian age, has long been debated. Specimens of two species here described show small but distinct eyes on the facial suture further forward than they had been alleged to occur in the known species from Oesel. Somewhat similar reduced eyes in the trilobites have occasionally been called "ocelli", but no eyes truly homologous with the ocelli or median eyes of Merostomata and of various Crustacea have hitherto been demonstrated. Both Beecher and Cowper Reed, however, have suggested that the distinct and isolated tubercle on the median line of the glabella in *Trinucleus* may be such a median eye. Dr. Ruedemann now maintains the correctness of that suggestion, and extends it to most, if not all, trilobites, for the following reasons. Such a tubercle is found in many species belonging to over thirty genera, and its frequent association with a smooth glabella proves that it had some use. In *T. tessolatus*, of which he gives good figures, and in other species, he has found evidence of a lens, not crystalline, but probably a sack filled with fluid. The test is thinner over the tubercle. The tubercle is more prominent in early growth-stages, as are true ocelli, and is well developed when the lateral eyes are aborted. It is always on the highest point of the glabella, generally between the lateral eyes, and often at the hinder end of a short crest which may indicate the course of the nerve. An ocellar tubercle or mound is commonest in Ordovician and Silurian trilobites. In Cambrian genera there is some evidence of transparent spots. In Devonian genera the strong development of the lateral eyes may have led to the loss of the median eye. The occurrence of a median eye in many primitive arthropods renders it *a priori* probable that such an organ was also possessed by the trilobites.

The discovery of a median eye in *Trinucleus* showed that the vestigial eyes of that genus were not ocelli but lateral eyes, and suggested search for the sutures on which they should occur. The detection of these here and elsewhere corroborates the views of Jaekel, Richter, and Swinnerton (Geol. Mag., 1915, p. 490) and upsets the Order Hypoparia. The search also led to the discovery of a new suture, which starts from a minute tubercle at the front end of the short crest mentioned above, and diverges to enclose the middle region of the front end of the glabella. Dr. Ruedemann suggests that this is "the rostral piece or epistoma . . . drawn up into the glabella by the exceptional swelling of the frontal lobe of the glabella and the development of the broad brim".

Enough has now been said to show how the palæontologists of

New York State are still making us their debtors, and to warrant our once more exclaiming with Miranda:

O wonder!
How many goodly creatures are there here!
O brave New World, that has such people in't!

F. A. Bather.

II.—Mesozoic Insects of Queensland. By R. J. Tillyard. (1) Planipennia, Trichoptera, and the new Order Protomecoptera; (2) The Fossil Dragon Fly *Æschnidiopsis flindersiensis* (Woodward) from the Rolling Downs (Cretaceous) Series; (3) Odonata and Protodonata; (4) Hemiptera Heteroptera; the Family Dunstaniidæ. Proc. Linn. Soc. N.S. Wales, xlii, pp. 175–200 (1917), 676–92 (1918); xliii, pp. 417–36, 568–92 (1918).

THE first, third, and fourth of these papers deal with the insects of the Ipswich Beds (Upper Trias) of Ipswich, Queensland. It is stated to be a definitely Mesozoic fauna, not unlike that of the Lias of England, but including a number of older forms apparently relics of the Coal-measure fauna; it is especially interesting because it fills up a gap in the succession of insect faunas owing to the hiatus in the Trias of the Northern Hemisphere. *Protopsychopsis* is a new genus of the Order Neuroptera Planipennia; *Mesopsyche* and *Triassopsyche* are new genera of the Trichoptera. The new Order Protomecoptera, including *Archipanorpa*, n.gen., forms a connecting link between the Palæozoic Palæodictyoptera and the recent Mecoptera. New genera of Odonata are *Triassolestes* and *Perissophlebia*. *Aëroplana*, n.gen., of which the venation does not show any close relationship to that of any other insect, either fossil or recent, is referred to a new sub-order (Aeroplanoptera) of the Protodonata. The affinities of *Dunstania* are discussed at considerable length; it was formerly regarded by the author as belonging to the Lepidoptera, but is now referred to the Hemiptera Heteroptera. Two new genera (*Dunstaniopsis* and *Paradunstania*), allied to *Dunstania*, are described.

The second paper deals with a dragon-fly from the Rolling Downs Series (Cretaceous) of Flinders River, North Queensland. This was originally described by Dr. H. Woodward (1884), who recognized its relationship to *Æschnidium* from the Purbeck Beds of Dorset. This specimen is described in detail by Dr. Tillyard, who regards it as the type of a new genus, *Æschnidiopsis*.

III.—Permian and Triassic Insects from New South Wales, in the Collection of Mr. John Mitchell. By R. J. Tillyard. Proc. Linn. Soc. N.S. Wales, vol. xlii, pp. 720–56, 1918.

THE Permian insects described in this paper come from the upper part of the Newcastle Coal-measures, which are generally classed as Permo-Carboniferous on account of the affinities of the marine fauna. The insects are associated with a *Glossopteris* flora, and have nothing in common with any known Carboniferous fauna, but show distinct affinities with Triassic forms. New genera of the Hemiptera Homoptera are *Permoscarta* and *Permofulgor*, the latter believed to have close affinity with the ancestors of the recent Fulgoridæ. The

Mecoptera are represented by *Permochorista*, n.gen., from which it appears that the Mecoptera are probably the most ancient of all Holometabolous insects.

The Triassic insects come from the Wianamatta Shale Beds at horizons from 300 to 700 feet above the Hawkesbury Sandstone, and are regarded as of Upper Triassic (probably Keuper) age. *Notoblattites* was originally placed in the Blattoidea, but is now referred to the Protorthoptera, and it is suggested that the cockroaches do not really belong to a separate Order, but are a specialization from a very ancient Protorthopterous type. *Mesopanorpa*, n.gen., is referred to the Mecoptera. The Coleoptera are represented by *Ademosyne*, *Elateridium*, *Adelidium*, n.gen., and *Metrorhynchites*; the Hemiptera Homoptera by *Triassopsylla*, n.gen.

IV.—Iron Ores of Scandinavia.

Jernmalm og Jernverk. By J. H. L. Vogt. Norges Geol. Undersök, No. 85, pp. 181, with 4 figs. Kristiania, 1918.

THIS important memoir of the Norwegian Geological Survey consists of two parts; the first part includes a review of the iron-ore production of Norway in recent years and especially since the publication of the author's earlier work, *Norges Jernmalmforekomster* (1910), together with statistics of export, import, and consumption of iron, import of coal and coke, and prices of ore and of pig-iron. It is interesting to find that in 1915 Sydvaranger produced, by magnetic concentration, 600,000 tons of 65 per cent ore, of which nearly half was briquetted; this ore contains no titanium, chromium, or vanadium, while phosphorus and sulphur amount to only 0·012 per cent in the concentrates; the production is expected shortly to reach 900,000 tons per annum. But of the $3\frac{3}{4}$ million tons of iron-ore shipped from Norwegian ports in 1913, $3\frac{1}{4}$ million tons were Swedish ore, mainly from Kirunavaara, exported via Narvik. About eighty pages are occupied by a full and detailed account of the mining districts of Arendal, Kragerö, Nissedal, Nordmöre, Trondhjem Fjord, Tromsö, and Sydvaranger, as well as the less important occurrences of Bogen and Dunderlandsdal. Owing to its importance to Norwegian export trade and commerce in general, a description is also given of the Swedish Kiruna ore, with analyses of the different grades, now reduced to four in number, A, C, D, and G. These range from a low-phosphorus ore (A) with 0·015 per cent P, to a type with 3 per cent or more of phosphorus, due to a high proportion of apatite in the differentiated mass. The highest quality contains about 69 per cent Fe, and is one of the finest ores in the world. By agreement with the Swedish Government this quality is reserved for home consumption in Sweden, where it is transported by rail to the amount of about 50,000 tons per annum. Over 80 per cent of the whole export via Narvik consists of high phosphorus ores, D and G, specially adapted for basic steel.

The last sixty pages of the memoir are occupied mainly by a discussion of the relative advantages of electric furnaces over ordinary blast furnaces for the home manufacture of pig-iron from

Norwegian ores. It is concluded that, owing to the abundance of water-power and absence of coal, the building of ordinary blast furnaces would be an economic mistake, since the fuel-consumption in an electric furnace is approximately only about one-third of that in a blast-furnace, and water power is cheap. It is estimated that the power consumption in an electric furnace is about 2,200 kilowatt-hours per ton of pig, which is equivalent to 3·98 tons of pig per kilowatt-year, or 2·92 tons per horse-power-year. Hitherto, the Swedish electric furnaces have been largely worked on charcoal, but coke is now extensively employed and gives good results. It is considered that small furnaces of the Tinfos type, working at about 1,500 kilowatts are not quite so economical as the larger Electro-metal furnaces of 3,500–4,000 kilowatts, but under certain circumstances they are perhaps better suited to a budding industry, being altogether on a smaller scale and needing less capital outlay.

From the data here supplied it is clear that in a country like Norway, with no coal and abundant water-power, electric furnaces offer great possibilities for the production of pig-iron for steel making for home consumption during periods of stress like the present time, when freights are high and dumping impossible, but it remains to be seen whether they will be able to compete with imported manufactured and half-manufactured goods on the return of more normal conditions of foreign competition and cheaper low-grade raw materials worked on a very large scale in England, America, and Germany.

R. H. R.

V.—Report on the Geology of the Hohoro District, Papuan Oilfield. By W. G. Langford. Bulletin of the Territory of Papua, No. 4, 16 pp., with 12 figs. and maps. Melbourne, 1918.

IN this report Mr. Langford gives an account of the physiographic features and geology of part of the Vailala oil-bearing district of Papua, where the existence of gas-blows has been known for some time. The essential structure is an elongated dome or anticline traversed by faults and consisting of sandstones, mudstones, and limestones, with occasional seams of lignite of Middle or Upper Miocene age. The rocks are highly fossiliferous and the fossils are described in a separate report. Sites have been selected for trial bores, and development is now in active progress.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *June* 4, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The following communications were read:—

1. "On the Dentition of the Petalodont Shark, *Climaxodus*." By Arthur Smith Woodward, LL.D., F.R.S., P.L.S., F.G.S.

The author describes the nearly complete dentition of a new species of *Climaxodus* from the Calciferous Sandstone of Calderside, near East Kilbride (Lanarkshire), now in the Royal Scottish Museum, Edinburgh. Nearly all the teeth are borne on the

symphysis of the jaw, only the outer paired longitudinal series extending a little farther back over the rami. There are from three to five longitudinal series, each of five or six teeth of the ordinary *Climaxodus* type, covering the greater part of the symphysis; and the flanking paired series, which extends farther back, comprises more depressed teeth, in which the cutting-edge forms a low blunt ridge. The two jaws are nearly similar; but, as in *Janassa*, the upper seems to have been slightly wider than the lower jaw. The teeth rapidly increase in size backwards, also as in *Janassa*, but they must have been all retained in the mouth throughout life; while in *Janassa* only a single transverse row would be in function at one time, the older teeth being thrust beneath to form a supporting base. *Climaxodus* and *Janassa* are thus two distinct genera. These Petalodonts are especially noteworthy among the Elasmobranchii, because during the greater part of the life of each individual there cannot have been more than six or eight teeth in succession, a condition remarkably different from ordinary sharks and skates in which the successional teeth are always very numerous and rapidly replaced. The same limited tooth-succession is to be observed in the Carboniferous Cochliodontidæ, and perhaps also in the contemporaneous Psammodontidæ. Most of the teeth of *Climaxodus* are also interesting as showing a restricted area of highly vascular dentine much resembling a tritor in the dental plate of an ordinary Chimæroid. This character in Elasmobranch teeth which are peculiar for their slow and scanty succession, may have some special significance in connexion with the origin of the Chimæroids.

2. "A New Theory of Transportation by Ice: the Raised Marine Muds of South Victoria Land (Antarctica)." By Frank Debenham, B.A., B.Sc., F.G.S.

A series of deposits of marine muds are found on the surface of floating "land-ice" in the deep bays of Ross Sea (Antarctica). Similar deposits are also found on land up to a height of 200 feet, in some cases on old ice, in other cases on moraine. The deposits are briefly described, and former theories concerning them are discussed.

A new theory is put forward, prefaced by an account of the nature of the typical ice-sheet which bears them. The upper surface of the sheet is known to suffer a net annual decrease, and evidence is given to show that the lower surface has a net increase by freezing from below.

The theory is that the sheet will freeze to the bottom in severe seasons, and enclose portions of the sea-floor. Owing to the method of growth of the sheet by increments from below, the enclosed portions will ultimately appear on the surface, thus being raised vertically as well as translated horizontally.

The application of the theory to other localities is briefly sketched, with especial reference to the shelly moraines of Spitsbergen and the shelly drifts of the glacial deposits of Great Britain. The general results of such a method of transportation are shown to be the raising of marine deposits above their initial level, the preservation of the organisms, the deposition of small patches of muds with

ordinary supra-glacial moraine, and the collection of remains of fauna from different depths in one horizon.

2. *June* 25, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The following communications were read:—

1. "Outlines of the Geology of Southern Nigeria (British West Africa), with especial reference to the Tertiary Deposits." By Albert Ernest Kitson, C.B.E., F.G.S., Director of the Geological Survey of the Gold Coast.

The oldest rocks in Southern Nigeria comprise a series of quartzites, schists of various kinds, blue and white marble, grey limestones, altered tuffs and lavas, amphibolites and gneisses. Their strike varies from west-north-west and east-south-east to north-east and south-west. They occur in the north-western portion of the country (Yorubaland), north of lat. 7° N., and in the Oban Hills region in the east. They may be classed provisionally as Pre-Cambrian. Intruded into these are large masses of granites of various kinds, syenite and diorite, with pegmatite and aplite dykes. In some parts these rocks have shared in the dynamic alteration to which the oldest series has been subjected; but usually they are practically unchanged. There is no definite evidence to show to what period they belong, but they are certainly Pre-Cretaceous, probably Middle and Early Palæozoic.

So far as observed, there is a great hiatus between the Pre-Cambrian and the next known sediments, the Upper Cretaceous. Normally, these are slightly inclined rocks: they include (1) Marine fossiliferous shales, mudstones, limestones, and sandstones in the great valley between the Oban Hills and the Udi plateau. The fossils are principally ammonites and mollusca; (2) Estuarine fossiliferous carbonaceous shales, mudstones, and sandstones along the eastern foot of the Udi escarpment; (3) Lacustrine sandstones, shales, and black coal-seams, with numerous plant-remains; and (4) Fluvio-lacustrine sands, shales, and pebble-bands in the lower and upper parts of the Upi plateau.

Flanking this plateau on the south and south-east, and extending thence over the southern part of the great valley to the Cross River, is a series of Eocene estuarine shales, clays, and marls, with septarian nodules and pieces of coal and resin, and a rich fauna consisting principally of mollusca, but including fragmentary remains of whales, birds, fishes, and turtles.

A thick series of sandstones, mudstones, shales, and seams of brown coal forms a large portion of the basin of the Niger, west of the Udi plateau. These rocks appear to be of lacustrine origin, and are probably Eocene. They contain numerous remains of undetermined plants, largely of dicotyledonous types. Their relation to the Cretaceous and to the Eocene estuarine series is uncertain.

In the Ijebu Jebu district are bituminiferous sands and clays with Pliocene estuarine shells.

Extending over practically the whole of the country south of lat. 7° 10′ N., and west of the great valley of the marine Cretaceous

is a varying thickness of (usually unstratified) clayey sands, probably late Pliocene—the Benin Sands Series of Mr. J. Parkinson.

Along the coast-line and extending for considerable distances up the Niger and Cross Rivers are fluviatile, deltaic, littoral, and swamp gravels, sands, and muds of Pleistocene and recent age. In the Cross-River basin, intruded into the marine Cretaceous, are volcanic necks of decomposed agglomerate, and sills (?) and dykes of olivine-dolerite. These are probably Pre-Eocene.

Faulting and local folding are visible in various portions of this district. Numerous silver-lead-zinc-iron lodes occur along these fault-lines, with brine-springs in several localities.

The Yorubaland crystalline rocks contain magnetite in considerable quantities, while these and the crystalline rocks of the Oban Hills show smaller quantities of cassiterite, gold, monazite, and columbite.

2. "Notes on the Extraneous Minerals in the Coral Limestones of Barbados." By John Burchmore Harrison, C.M.G., M.A., F.G.S., F.I.C., and C. B. W. Anderson.

Characteristic representative specimens of the fossil reef-corals and of the beach-rock of the high-level and low-level limestone terraces of Barbados were examined chemically and microscopically, in order to ascertain the composition, nature, and origin of their extraneous mineral contents. A special method was used, whereby the extraneous mineral matters were separated, practically without alteration, from large quantities of the limestones. Chemical analyses of the residua were made, and the results of these and of the microscopical examinations are tabulated in the paper. The extraneous minerals present were found to be apparently fresh and largely unaltered fragments of wind-borne volcanic minerals and glass. It was found that the volcanic minerals enclosed in the reef-corals on which they fell have been protected from change; those in the clastic limestone or bed-rock show signs of detrition and weathering prior to the consolidation of the limestone. Similar minerals separated from clay normally formed and accumulated in a pothole in the limestone supply evidence of weathering changes after being set free from the rock. It is shown that the composition of the sedentary residual soils on the higher limestone terraces of Barbados corresponds in its essential parts with the residua separated, either naturally or artificially, from the limestone.

The proportions of magnesium carbonate present in the coral-rock are briefly discussed, and complete analyses of the high-level and the low-level limestones are given. A note on the proportions of titanium oxide in the Barbados Oceanic clays and in some of the *Challenger* and *Buccaneer* deep-sea dredgings is appended to the paper.

II.—Mineralogical Society.

June 17, 1919.—Dr. A. E. H. Tutton, F.R.S., Past-President, in the Chair.

A. E. Kitson: "Diamonds from the Gold Coast." The crystals and their occurrence were described.

A. Brammall: "Andalusite (Chiastolite); its Genesis, Morphology, and Inclusions." In a survey of thermometamorphic "spotted" rocks evidence based on structural features, optical properties, and microchemical reactions is adduced to show that certain types of spots convergent towards such minerals as chiastolite, andalusite, cordierite, mica, and chloritoid record arrested development, and that they are probably ontogenetically related. The spot is a complex system containing a volatile phase, water, and its development involves metamorphic diffusion and differentiation controlled by changing conditions of temperature and stress, the tendency being towards the attainment of an equilibrium end-point in a metastable mineral. Thermal and stress conditions adequate to initiate the tendency may be inadequate to sustain it, the time factor also being involved; development may be arrested and abortive effort recorded as a mineral "spot", the nature of which is determinable, but is often vague or wholly conjectural. The chemical and physical characters of argillaceous sediments are considered with special reference to the genesis of chiastolite. Clays contain a high proportion of hydrated silicates of alumina readily soluble and in part probably colloidal. On rise of temperature diffusion effects the segregation of the primary clot; diffusion inwards of allied molecules and diffusion outwards of alien substances tend to promote homogeneity and reconstitution within the spot, the peripheral zone being maintained for a time in a relatively high state of hydration. In this connexion the peripheral zone of yellow-brown, non-pleochroic, and isotropic stain is significant; microchemical tests show that it is due to ferric hydrates, which are known to be liable to spontaneous dehydration, and it is suggested that the ferric hydrate in the peripheral stain acts as a catalyst, assisting dehydration within the spot and transmitting water to the base. For chiastolite (andalusite) a mechanism of formation is suggested to cover the observed facts, to explain the characteristic distribution of its opaque inclusions, and to account for crystals which have the superficial aspect of cruciform twins.

R. H. Rastall: "The Mineral Composition of Oolitic Ironstones." In many oolitic ironstones the ooliths contain more iron or are more highly oxidized than the matrix. Assuming that the iron-content of such rocks is introduced by metasomatism of calcium carbonate, this may be explained in the following way. Many ooliths and organic fragments in limestones consist of aragonite, while the cement is calcite. Aragonite is less stable than calcite and more readily decomposed by iron-bearing solutions, which therefore attack the aragonite first, while the calcite is replaced later. Hence we have the following scheme in successive stages:—

Ooliths.	Aragonite	→ Chalybite	→ Limonite.
Matrix.	Calcite	— Calcite	→ Chalybite.

The ooliths are always a stage ahead of the matrix in replacement and oxidation. The origin of the green iron silicate, found in many ironstones, requires further investigation.

L. J. Spencer: "Eighth List of Mineral Names."